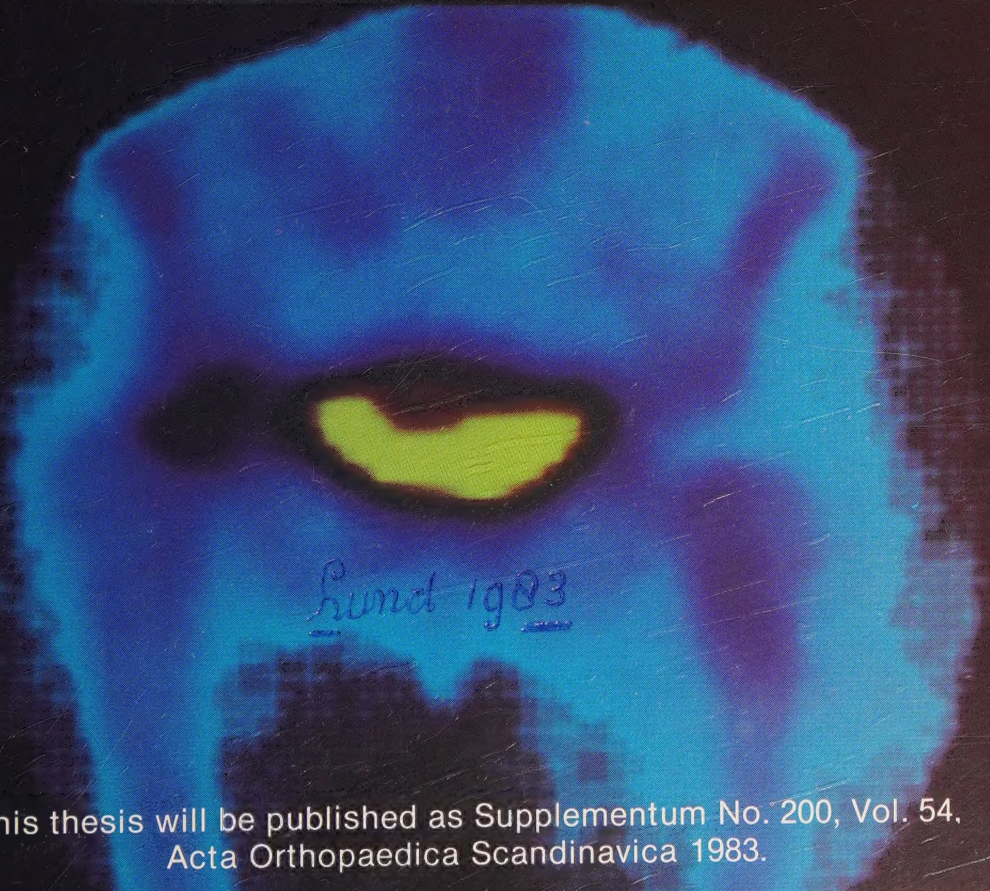
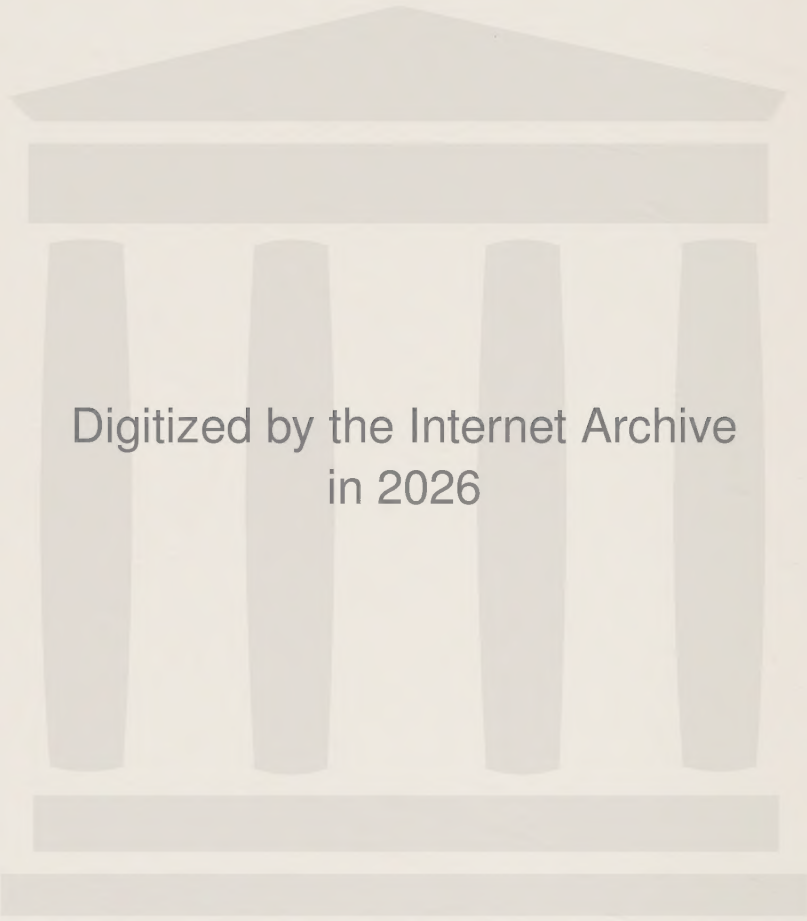


Femoral Head Vitality After Intracapsular Hip Fracture

Björn Strömqvist



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From the University Department of Orthopaedics in Lund, Sweden

Femoral Head Vitality After Intracapsular Hip Fracture

490 Cases Studied by Intravital Tetracycline
Labeling and Tc-MDP Radionuclide Imaging.

BY

BJÖRN STRÖMQVIST

'A fracture of the neck of the thigh-bone never unites; tell the patient this, and that he must be lame for life.'

John Pulley as quoted by Astley Cooper, 1824



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I Introduction

The pathophysiologic characteristics of the femoral neck fracture were demonstrated more than 150 years ago (Cooper 1824) as a result of clinical observations and animal experiments. Recognition of the injury inflicted on the vascular supply to the femoral head by an intracapsular fracture of the hip led Cooper to the conclusion that this fracture could not heal. The nihilistic approach to therapy which logically followed was modified after Röntgen and Lister. Whitman (1902) and Löfberg (1911) showed that the femoral neck fracture could heal after reduction and plaster fixation. Smith-Petersen (1931) introduced open nailing by the three-flanged nail, and Johansson (1932) the cannulated nail and two-plane radiography permitting fixation without exposure of the fracture.

While this development in part has solved the mechanical problem of fracture apposition and fixation and has shown that Cooper was wrong in his conclusion on fracture union, his pathophysiologic concept is still valid. The vulnerability of the blood supply to the femoral head is the main reason for the high complication rates encountered today, 10—20 per cent after undisplaced and 30—60 per cent after displaced fractures (Banks 1962, Garden 1971, Massie 1973, Barnes et al 1976, Bentley 1980); this is the background for the policy of primary hip arthroplasty for displaced fractures (Hinchey and Day 1964, Salvati and Wilson 1973, Tillberg 1976).

The crucial point regarding healing complications thus is the femoral head viability (Phemister 1934, Hulth 1958, Rokkanen and Slätis 1974). However, mechanical factors, notably poor fracture reduction and fixation may contribute (Deyerle 1965, Garden 1971, Arnoldi and Lemperg 1977, Thorling 1980), and already a decade ago more than 60 devices for femoral neck fracture fixation had been developed (Tronzo 1974), the majority of which have aimed at increasing fracture stability.

The fracture moment has generally been regarded as the time of occurrence of circulatory deprivation although potential threats later in the course have been pointed out (Hulth 1956, Lowell 1980, Höivik 1981). The possibility of nailing as the cause of injury to the femoral head vascularization has been proposed (Linton 1944, Sevitt 1981) but not proven. Even today the literature contains no controlled comparative studies regarding vascular or mechanical effects of different methods of osteosynthesis.

Radiographic signs of healing complications are mainly secondary to vascular/metabolic disturbance and as such late in appearance. This has initiated the search for a method for determining femoral head vitality at an early stage. Numerous invasive

methods of studying vascularization or metabolism have evolved (Tucker 1950, Boyd 1951, Arden 1960, Johansson 1964b, Hulth 1965, Müssbichler 1970). Better vascularization in undisplaced than in displaced fractures could be demonstrated, and prediction accuracy was rather satisfactory, but technical errors were frequent, and the invasiveness of the methods restricted their use.

Bauer and Wendeberg (1959) showed by noninvasive scintimetry that femoral neck fractures had a high uptake of ^{47}Ca and ^{85}Sr . Femoral head hypermetabolism in the preradiographic stage of non-traumatic (Cameron 1969) and post-traumatic (Asnis et al 1976) osteonecrosis was demonstrated with ^{85}Sr ; it has however not proven possible to demonstrate post-fracture hypometabolism using this isotope (Brümmer et al 1982). The visualization of early postoperative femoral head deficiency of ^{18}F (D'Ambrosia et al 1975) and $^{99\text{m}}\text{Tc}$ -diphosphonate (D'Ambrosia et al 1976) meant further progress for scintimetry in avascular disorders of the femoral head.

Much interest has been focused on femoral neck fractures at the Department of Orthopaedics in Lund. In the early sixties hemiarthroplasty was performed as the primary procedure for displaced fractures in patients above 70 years of age, while in the latter part osteosynthesis with a four-flanged nail (Rydell 1964) was introduced. In the seventies, economic and epidemiologic (Borgquist 1974) as well as sociologic (Ceder 1980) aspects of hip fracture were explored.

With this background the present investigation started in Lund in 1978 where Göran Bauer with a long background of isotope techniques (Bauer et al 1955, Bauer and Wendeberg 1959, Bauer 1968) and fracture epidemiology (Bauer 1960, Alffram and Bauer 1962), Lars Ingvar Hansson with experience from intravital studies by tetracycline (Hansson 1964, 1967, Hansson et al 1972) and osteosynthetic techniques (Hansson 1975), David A. Weber, Rochester, N.Y., experienced in isotope investigations of skeletal metabolism (Weber et al 1969, 1976, King et al 1977) and the author initiated a prospective long-term study of postoperative femoral head vitality and its correlation to the clinical and radiographical course (Bauer et al 1980, Strömqvist et al 1983b). Femoral head vitality before nailing was studied with tetracycline (Strömqvist et al 1981, Strömqvist and Hansson 1983b). The prognostic value of scintimetry was revealed, and in some cases a discrepancy between femoral head vitality before and after nailing was observed (Strömqvist and Hansson 1983a). This led to a study comparing pre- and postoperative vitality (Strömqvist et al 1983d) which showed that the four-flanged nail could increase the risk for peroperative circulatory injury. The possibility of reducing vascular injury with a less traumatic method of osteosynthesis was explored (Strömqvist et al 1983c). Parallel to these studies, tests on the reliability of the methods were performed.

Detailed results have been presented during the progress of the investigations. This presentation, focused on femoral head vitality, summarizes the results, in part by adding material from different sub-sets; on this basis an attempt is made to draw conclusions on the treatment of the femoral neck fracture.

II Probands

The material consisted of 490 patients, 367 females and 123 males, treated for intracapsular femoral neck fracture from October 1978 through February 1983 (Table 1). Four hundred and sixty-nine of these were admitted to the University Hospital in Lund, and 21 to the District Hospital in Helsingborg (II. C).

The total material was composed of six sub-sets, described under the titles A—F in this chapter; there was considerable overlap between the sub-sets (Figure 1).

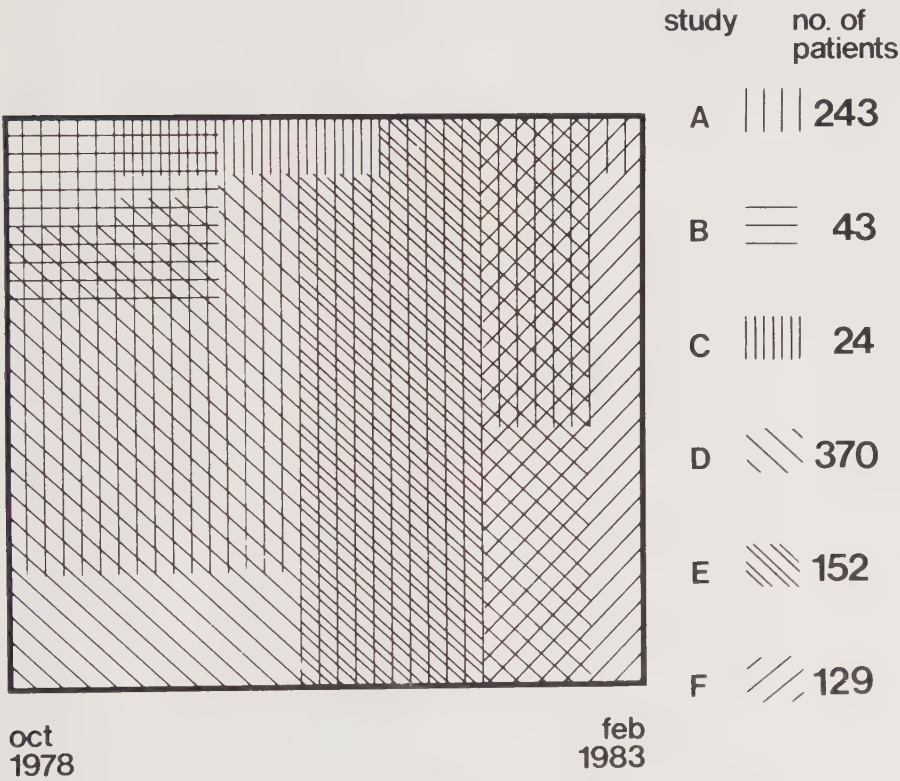


Figure 1 Total material of femoral neck fractures and sub-sets A—F, demonstrating the degree of overlapping and approximate periods of studies . 1 cm² $\approx$ 8 fractures.

Table 1 Age, sex, fracture displacement and method of osteosynthesis used in total material and in sub-studies.

	No of patients	Mean age	Range	Ratio female/male	Fracture displacement			Method of osteosynthesis		
					Garden I—II	Garden III	Garden IV	4-flanged nail	Hook-pins	Other method
Total material	490	77	18—98	3.0:1	137	121	232	276	212	2
A	243	76	18—95	2.5:1	61	54	128	134	109	—
B	43	72	18—91	3.5:1	9	12	22	35	6	2
C	24	73	43—92	1.6:1	6	4	14	24	—	—
D	370	77	18—98	2.8:1	103	87	180	251	119	—
E	152	78	52—95	2.1:1	42	33	77	70	82	—
F	129	77	48—95	3.1:1	32	28	69	—	129	—

Femoral head vitality was determined by tetracycline labeling and ^{99m}Tc-MDP scintimetry in 223 cases, tetracycline labeling only in 162 cases and scintimetry only in 105 cases. During the first year, the limited capacity of the isotope laboratory determined the number included in the scintimetric study, while expansion in the autumn 1980 made radionuclide imaging of every patient in suitable condition possible (Figure 2). Each year about 120 fresh femoral neck fractures were admitted in Lund.

Only patients operated on by one of six surgeons familiar with the biopsy technique were included in the tetracycline study, and from the autumn 1980 on, these six surgeons operated every femoral neck fracture admitted (Figure 2). For inclusion in the study of patients in groups II.A—C and II.E—F, informed consent was required. Two patients with metastatic fractures were excluded; no other patients with ipsilateral hip disease were seen.

The patients' age was 77 (18—98) years; fifteen patients (3 per cent) were below 50 years of age. The fracture displacement was classified according to Garden (1961): 137 Stage I—II fractures, 121 Stage III fractures and 232 Stage IV fractures.

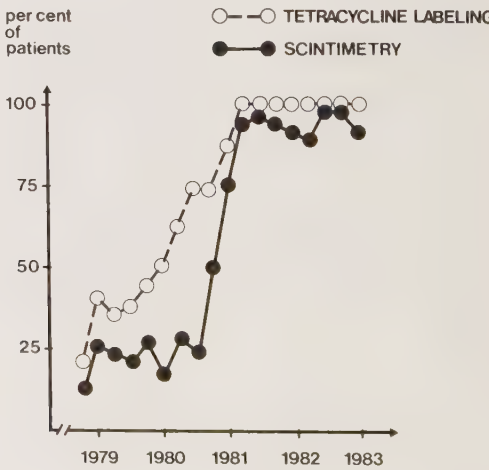


Figure 2 Per cent of total number of femoral neck fractures in Lund included in tetracycline and scintimetry studies. Annual number of fractures = 120—135.

Osteosynthesis was performed with the Rydell (1964) four-flanged nail (Figure 3) in 276 cases, the Hansson (1975, 1982) hook-pins (Figure 4) in 212 cases, and in one case each a three-flanged Thornton nail and the Richards' compression screw and plate.



Figure 3 a, b Femoral neck fracture before (a) and after (b) osteosynthesis with the four-flanged Rydell nail.



Figure 3 c Nine days postoperative scintimetry of fracture of Figure 3 a, b, with femoral head ratio 1.85.

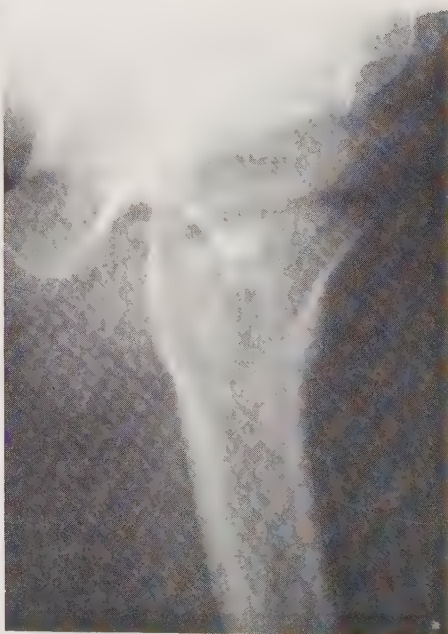


Figure 4 a Femoral neck fracture before osteosynthesis.

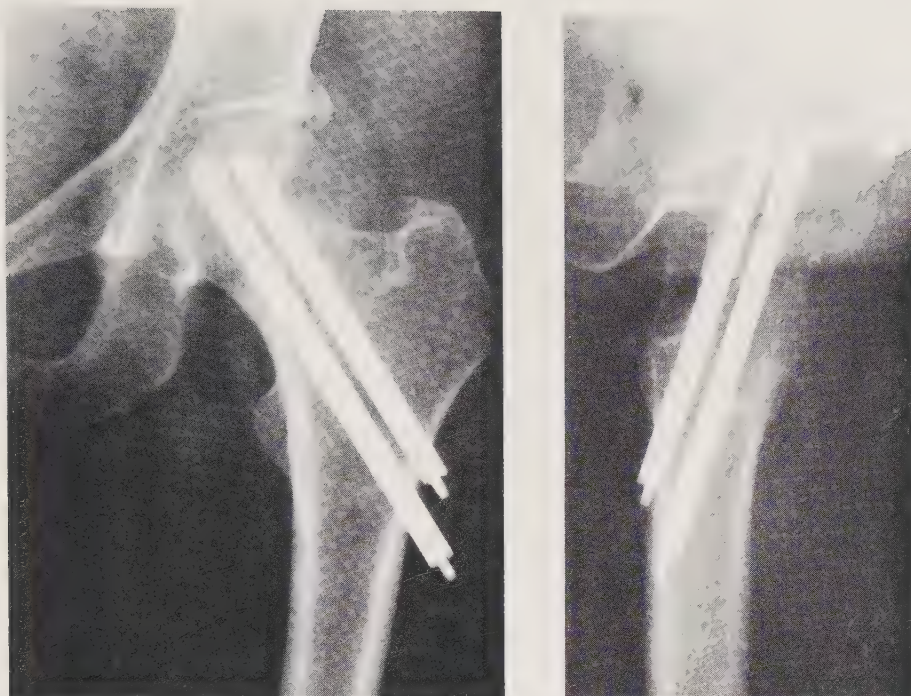


Figure 4 b Femoral neck fracture of Figure 4 a after osteosynthesis with two hook-pins.

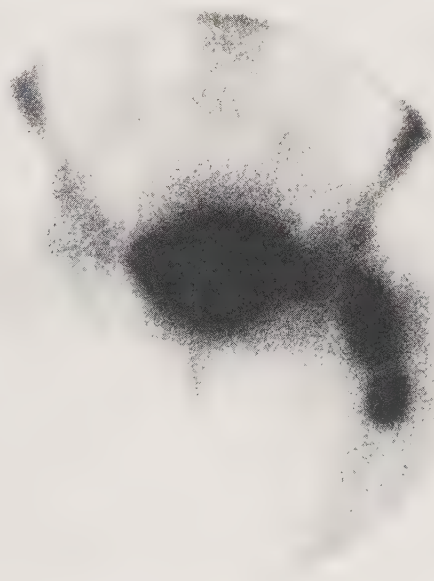


Figure 4 c Eleven days postoperative scintimetry, femoral head ratio = 1.95.

A. Methodologic studies

For assessing the sensitivity of tetracycline labeling determination by fluorescence microscopy, microspectro-fluorometry (III.C:4b) was performed in 52 femoral head biopsies with preoperative tetracycline labeling (Strömqvist et al 1981).

Tetracycline distribution estimation with the aid of the morphometric point-wave pattern (III.C:4c) was carried out in 30 femoral head and trochanteric biopsies with peroperative tetracycline labeling (Strömqvist and Hansson 1983b).

Visual versus numerical evaluation of femoral head scintimetry (III.D:2a) was performed for the first postoperative 2—20 days and the four month scintimetry of cases described in II.B. (Strömqvist et al 1983b).

Correction for soft-tissue uptake (III.D:2b) was performed in scintimetries of the cases described in II.B and E (Strömqvist et al 1983b, c).

Biopsy scintimetry (III.D:2c) was carried out in 20 cases, and 17 of these had simultaneous tetracycline and isotope administration (III.E).

B. Three-year follow-up

Forty-three patients, 34 women and nine men, sustaining a femoral neck fracture between October 1978 and May 1980, were subjected to repeated ^{99m}Tc -MDP scintimetric, radiographic and clinical examinations for up to three years (Bauer et al 1980, Strömqvist et al 1983b). The mean age was 72 (18—91) years (Table 1). Nine fractures were undisplaced and 34 displaced. An intact contralateral hip and ability to cooperate were required for inclusion in the investigation. One patient refused follow-up, two died within eight months, and one developed osteoarthritis without relation to the hip fracture (narrowing of the joint line preceded remodelling of the femoral head). These four patients were excluded from the presentation which comprised 39 patients.

C. Pre- versus postoperative scintimetry

Twenty-four patients, 15 women and 9 men, mean age 73 (43—92) years, had preoperative scintimetry on the day of operation or the day before (Strömqvist et al 1983d). Prerequisites for inclusion were absence of contralateral hip disease, and that the preoperative examination would not delay the operation. For patients with pin traction, this was retained during the imaging procedure. Six patients had undisplaced and 18 displaced fractures. One patient died the day after the operation, and for one the postoperative scintimetry was not evaluable because of a technical error. Comparison between pre- and postoperative scintimetry (V.A) was thus performed in 22 patients.

Seventeen of these patients were re-imaged after four months; two patients had hip arthroplasty because of redisplacement and three patients died or were too weak for the examination.

D. Tetracycline labeling

In 370 patients, 273 female and 97 male, admitted 1978—1982, tetracycline labeling was performed (Strömqvist et al 1981, Strömqvist & Hansson 1983b) (Table 1). The mean age was 77 (18—98) years. Preoperative tetracycline administration was made in 63 patients with 14 undisplaced and 49 displaced fractures. Peroperative administration was made in 307 patients with 89 undisplaced and 218 displaced fractures.

E. Comparison of osteosynthetic methods

From January 1, 1981, through February 24, 1982, every patient above 50 years of age admitted to the Lund University Hospital for a femoral neck fracture was included in a comparative study where those born on even birth-dates had the nail and on uneven birth-dates the hook-pins (Strömqvist et al 1983c). In all, 152 patients, 103 women and 49 men, with a mean age of 78 (52—95) years were operated on by one of six surgeons with similar distribution of method of osteosynthesis. The operation was performed within two days from fracture except in two patients with complicating disorders and 16 who failed to seek immediate medical attention (delay 3—19 days). Six of these patients belonged to the nail group and 12 to the hook-pin group.

Fourteen patients were not subjected to scintimetry; three refused and 11 were in a poor general condition. Four patients were excluded because of contralateral hip disease. Of the 134 patients remaining for comparison 61 were operated on with the nail and 73 with the pins. The distribution of patients between the groups did not differ as regards age, sex, trauma, type of fracture and predisposing disorders.

In the nail group 16 fractures were undisplaced and 45 displaced; in the pin group, 21 were undisplaced and 52 displaced.

F. Hook-pin series

Every patient admitted to the Lund University Hospital for a femoral neck fracture during one year following the osteosynthetic comparison study was operated on with two hook-pins. 134 patients, 97 women and 37 men, with a mean age of 77 (48—95) years were operated on by one of six surgeons. For six patients the operation was performed more than two days from fracture.

Five patients were not submitted to scintimetry because of poor general condition; of the remaining 129, undisplaced fractures were registered in 32 and displaced in 97.

III Methods

A. Radiography

Standard AP and lateral projections of the affected hip and an AP view of the pelvis were obtained on admission, after operation and in connection with all clinical and scintimetric follow-ups.

Preoperative fracture displacement was determined according to Garden's (1961) classification although distinction between Stage I and II fractures was not made; they were called undisplaced and Stage III and IV fractures displaced.

Non-union (pseudarthrosis) was diagnosed when signs of fracture healing were absent at eight months or later. As redisplacement of the fracture, if untreated, most often leads to non-union, and non-union most often is associated with some degree of varus displacement, these "early" healing complications were regarded as an entity.

The diagnosis of segmental collapse was established according to the criteria of Brown and Abrami (1964), i.e. the recognition of a depressed segment of the femoral head, varying from a deep wedge to a thin cortical shell.

B. Fracture treatment

For fractures with marked displacement, pin traction was immediately applied. The operation was performed within two days from admission if contraindications were not present. With few exceptions, the operation was performed in general anaesthesia. An extension operating table and fluoroscopy, usually bi-plane, were used. Closed reduction was performed before nailing in all 353 displaced fractures.

Up to December 31, 1980, the nail was used as the routine method of osteosynthesis while the pin was used in a limited number of cases.

From January 1, 1981, patients born on even dates were operated on with the nail and patients born on uneven dates with pins. However, those below 50 years of age had pins as had every patient operated on later than February 24, 1982. Two patients were operated on elsewhere with the three-flanged Thornton nail and the Richards' compression screw and plate respectively.

From late 1980 all fractures were operated by one of six surgeons. The effect of this on fracture reduction and nailing results is being evaluated. For fractures in II.B and E developing redisplacement, retrospective scrutiny of the postoperative radiographs failed to identify predisposing factors such as inaccurate reduction or nail position.

Full weight-bearing was allowed from the first postoperative day except for four patients below 50 years of age with displaced fractures.

Institutionalized patients, usually admitted to a mental hospital for senile dementia, were operated on as out-patients (Hansson et al 1982). Hospitalization time for the remainder was 18 (3—134) days. In accordance with figures reported by Ceder et al (1980) about three patients out of four from their own home returned home without institutionalized rehabilitation.

Routinely, postoperative follow-up including clinical and radiographic examinations was performed every four months the first year and annually up to three years after the operation.

Nail extraction because of local lateral hip symptoms and hemi- or total arthroplasty because of healing complications were performed when indicated; inclusion in the study was not allowed to change the clinical management of the patients.

C. Tetracycline labeling

1. Administration

Tetracycline administration was performed pre- or peroperatively. Preoperative administration consisted of either 1000 mg of tetracycline (Achromycin®) or oxytetracycline (Terramycin®) *per os* in two equal doses with a four-six hour interval or 500 mg of oxytetracycline in 500 cc of saline in a four-six hour infusion. Administration was performed within 24 hours from admission and, for displaced fractures, after the application of pin traction. For peroperative administration, 500 mg of oxytetracycline or 200 mg of doxycycline (Vibramycin®) in 20 cc of saline was infused intravenously on the operating table during 10 minutes, after closed reduction, if performed, but before nailing.

2. Biopsy

The biopsies were taken from the channel of the nail centrally in the femoral head and, for most cases, also in the trochanteric region. The course for the distal pin was the same as for the nail so this channel was used for biopsies in pinned patients.

3. Histology

The biopsy specimens were fixed and dehydrated in ethyl alcohol (Hansson 1967) and embedded undecalcified in methyl-methacrylate (Ahlgren 1968). Sectioning was carried out manually or with the Isomet® device into 6—8 transverse sections of 75—300 μ thickness.

4. Evaluation

a. Fluorescence microscopy

The biopsy sections were examined under reflected light with a Leitz Orthoplan fluorescence microscope.

Yellow tetracycline fluorescence directly on the bone trabecular surface (Figure 5 a, b) was estimated for degree of distribution and intensity in each section and a mean

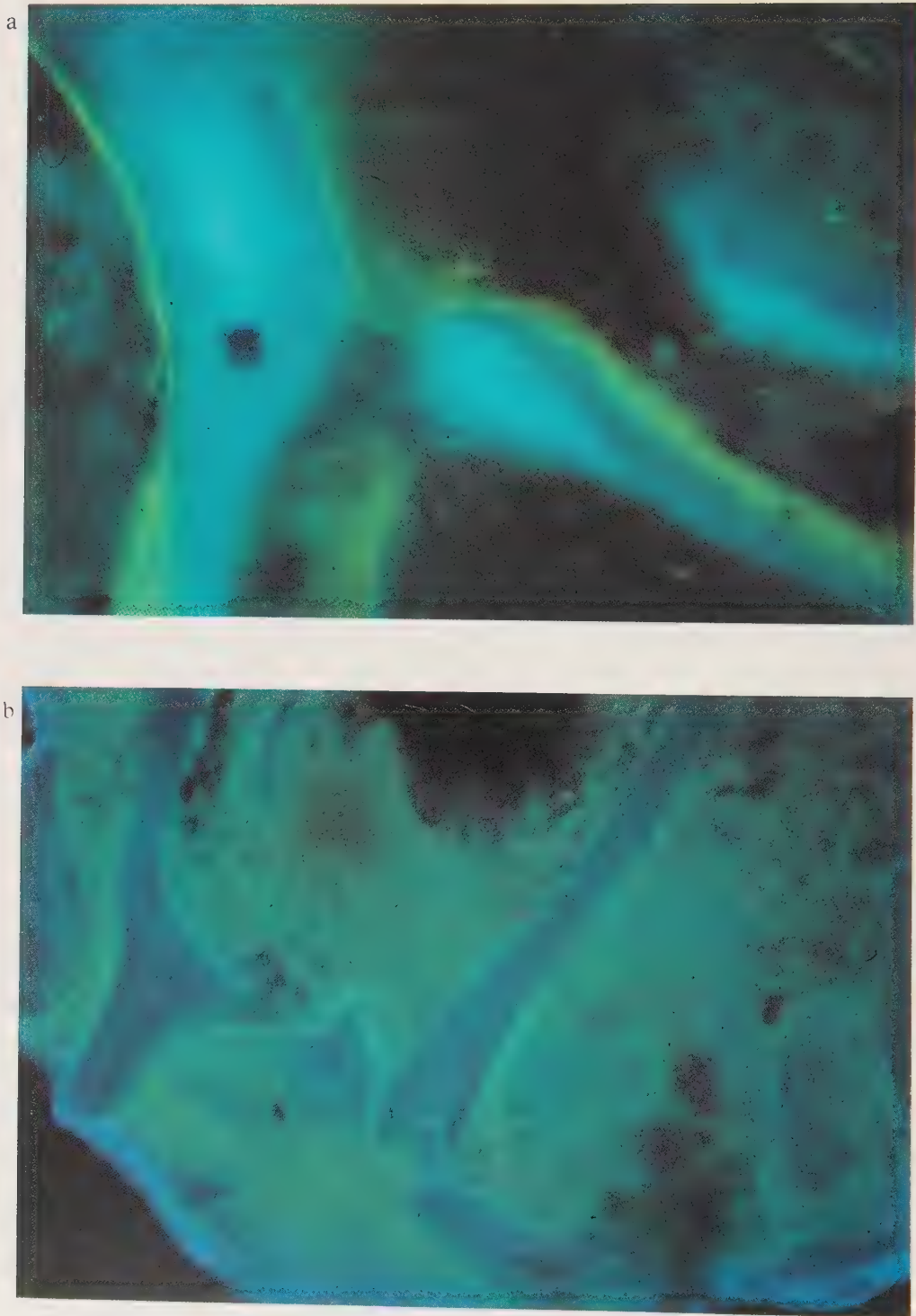


Figure 5 Fluorescence micrographs of femoral head biopsies with (a) and without (b) tetracycline deposition on bone trabeculae after tetracycline administration.

value was determined for each biopsy specimen. Ratios of the femoral head biopsy/trochanteric biopsy fluorescence were calculated for each fracture from these mean values. Trochanteric biopsy values varied over a small range regarding tetracycline distribution and intensity, ± 7 per cent, so for 41 fractures without such biopsies, the ratio was calculated using the mean trochanteric value of the total material. Recent tetracycline administration could be excluded for all patients except one; this fracture was not included in the study.

Ratios of femoral head biopsy/trochanteric biopsy ranged from 0.0 to 1.0. For one patient without fracture from whom biopsies were achieved, the ratio was 1.0. For three femoral neck fractures without tetracycline administration, ratios were 0.0. Only nine out of 370 patients had a ratio ≥ 0.90 , i.e. a femoral head labeling reduction less than 10 per cent of that of the trochanteric region.

b. Microspectro-fluorometry

A modified Leitz microspectro-fluorograph (Björklund et al 1968) was used to characterize the source of fluorescence in 52 femoral head biopsies labeled preoperatively. Emission spectrum for tetracycline showed a peak at 530—560 m μ and for oxytetracycline at 510—540 m μ .

In 43 out of the 52 biopsies visual labeling of varying degree was found and in all these microspectro-fluorometry showed the expected emission peak. Microspectro-fluorometry also indicated the presence of tetracycline in seven of nine biopsies where visual labeling was absent, even retrospectively. This indicates different sensitivities of the methods and that minor depositions of tetracycline may be undetectable visually.

c. Morphometric point-wave pattern

In order to evaluate the precision of the grading presented above (III.C:4a), visual grading of tetracycline labeling distribution was compared to measurements with the morphometric point-wave pattern developed by Merz and Schenk (1970). All sections of the femoral head and trochanteric biopsies of 30 fractures with peroperative tetracycline administration were examined with the templet, and a ratio femoral head/trochanteric region for mean values was determined.

The correlation to visual grading (Figure 6) showed that precise quantitative analysis of tetracycline labeling can be performed.

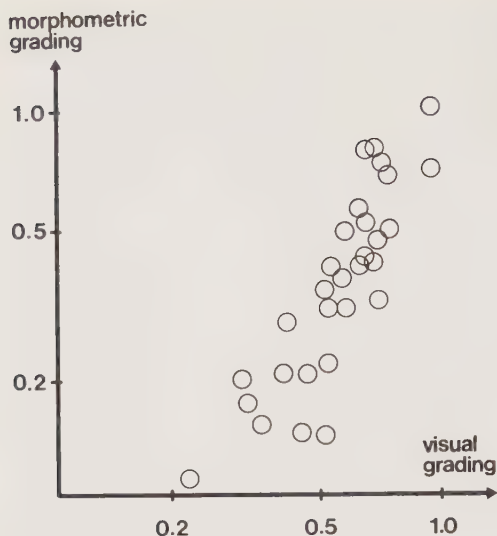


Figure 6 Tetracycline study. Correlation of femoral head/trochanter ratios estimated with the morphometric point-wave pattern and with visual grading.

D. ^{99m}Tc -MDP scintimetry

1. Imaging

Each imaging procedure followed intravenous administration of 330—380 MBq ^{99m}Tc -technetium methylene diphosphonate (^{99m}Tc -MDP). An AP view of the pelvis was recorded by the gamma camera with the aid of a parallel hole collimator. A dedicated computer system (Gamma 11) was used for image storage, processing and display.

a. Vascular phase

The initial blood pool distribution was measured in 15 fractures of II.B. 15-second images were obtained during the first five minutes and one minute images for the following 25 minutes. For seven of ten fractures with decreased femoral head isotope uptake in the metabolic phase (see III.D:1b), this could be visualized within ten minutes from isotope injection (Figure 7), while the other three showed no early filling defect and neither did the five patients with satisfactory femoral head uptake in the metabolic phase.

b. Metabolic phase

Radionuclide imaging was performed 3—4 hours after isotope injection. Collection time was three or six minutes.

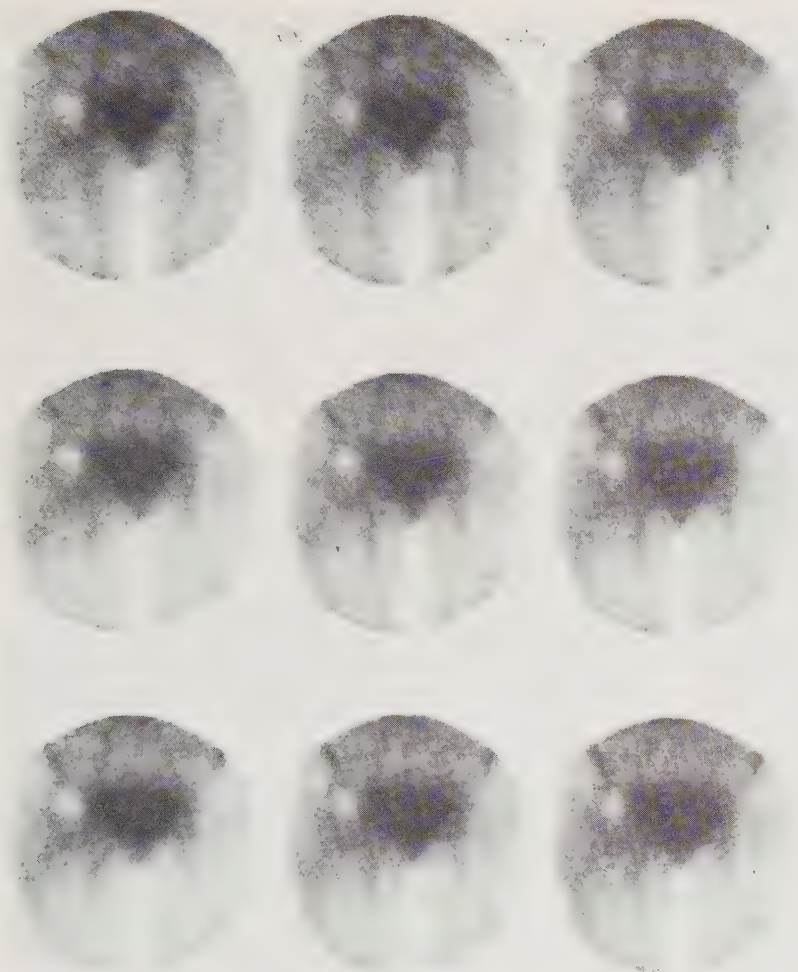


Figure 7 One minute ^{99m}Tc -MDP scintimetric images from eight minutes after isotope injection seven days after nailing of right-sided femoral neck fracture. Decreased activity is seen over the right femoral head.

2. Evaluation

All results discussed here refer to the image recorded 3—4 hours after injection.

a. Visual and numerical evaluation

Comparing the femoral head uptake on the fracture side with that of the intact side, four uptake categories were defined visually

- | | |
|--|------------------------|
| 0 = reduced activity | 2 = normal activity |
| 1 = partially/locally reduced activity | 3 = increased activity |



Figure 8 Scintimetry study. Close-up view of right hip with regions of interest (ROI).

With the computer's aid, regions of interest (ROI) were selected over the head, neck, trochanter and shaft of femur bilaterally in a standardized way (Figure 8) except in the pre- versus postoperative scintimetry study (V.A) where square regions of equal size were selected.

Uptake ratios fractured/intact side for the four regions were calculated and should be expected to be about 1.0 in the absence of hip disease or injury. In repeated ROI determinations by two persons independently, the error of the method of evaluation was below ± 5 per cent.

Evaluation performed visually and numerically by two persons independently in 75 scintimetries were compared (Figure 9). The correlation proved satisfactory with ratio

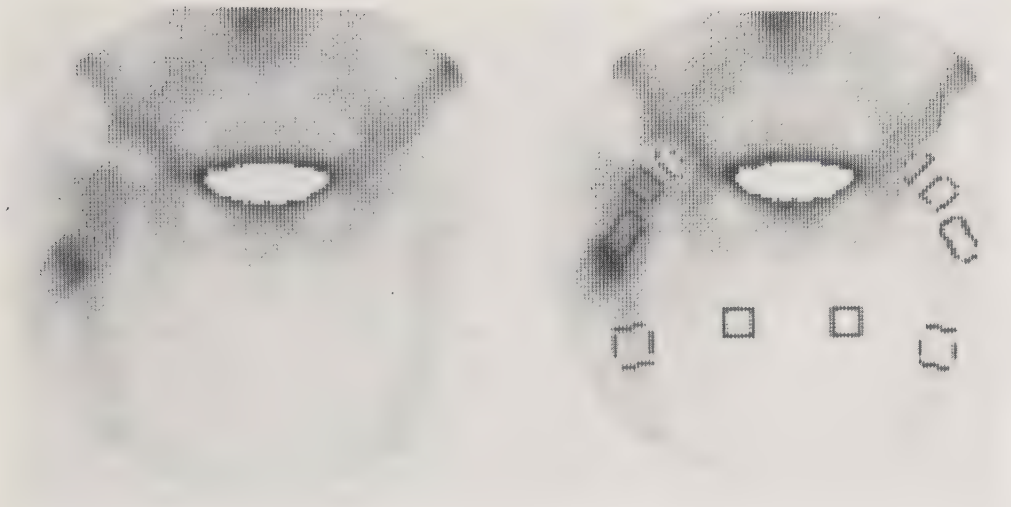


Figure 8 Scintimetry study. Method of selecting regions of interest (ROI) in the proximal femur.

≤ 1.0 in general activity reduction, $1.0\text{--}1.5$ in normal activity and > 1.4 in increased activity.

In the presence of high fracture activity, the femoral head uptake may be underestimated visually (Strömqvist et al 1983b); this was the reason for characterizing the uptake as reduced in two fractures with femoral head ratios of 1.10 and 1.32 respectively (Figure 9).

An obvious advantage with numerical evaluation is the possibility of statistical analysis.

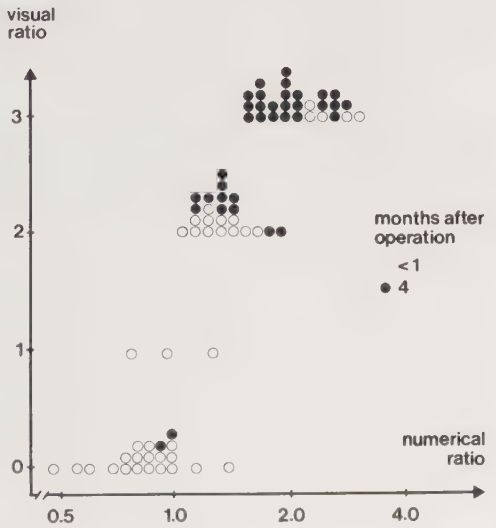


Figure 9 Scintimetry study. Correlation of visual and numerical estimation of femoral head uptake on fractured side compared with intact side. Visual grading ranged from 0 = decreased activity to 3 = increased activity. Numerical ratio denotes uptake femoral head fracture/intact side. $N = 75$.

b. Soft tissue correction

Even when imaging had been performed 3—4 hours after isotope administration, it was obvious in several cases that the soft tissues on the fracture side yielded an increased uptake compared to the intact side, especially if short time had elapsed since fracture or operation (Figure 10). In order to reveal if a low bone uptake might be demasked, soft tissue uptake was determined by ROI's medially in the adductor muscle region (Figure 8) and corrected for when determining femoral head uptake ratios for patients in II.B and II.E.

This correction did not alter the results significantly although a wider range for the ratios was obtained (Table 3). Ratios ≤ 1.0 uncorrected tended to be lowered by soft tissue correction and ratios > 1.0 increased. In one case only, the correction shifted the ratio past 1.0; a femoral head ratio of 1.11 was reduced to 0.98 by soft tissue correction. Soft tissue correction theoretically seems plausible but the selection of ROI might be a source of error. In the presentation below uncorrected ratios were used.

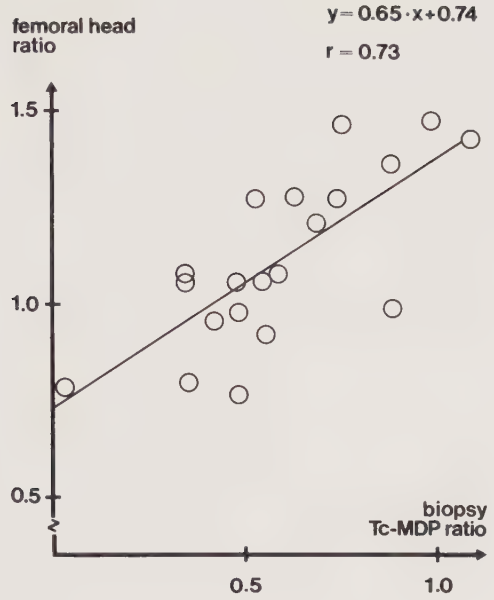
c. Biopsy scintimetry

In 20 fractures (II.A) preoperative scintimetry was performed on the day of operation. During the operation biopsies were obtained as described in III.C:2. Isotope activity of the femoral head and trochanteric region biopsies were determined in a well counter 5—8 hours after isotope injection; counting time 100 seconds. Subtraction of background activity and correction for weight of the biopsy specimen permitted calculation of specific activity (counts/g of bone tissue) and from this a ratio femoral head/trochanteric biopsy was determined.



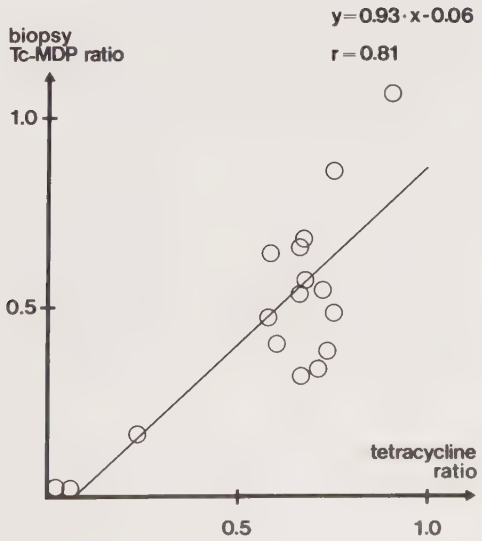
Figure 10 Scintimetric image of the pelvis of a 76-year old woman seven days after operation for left-sided femoral neck fracture. Note the increased soft-tissue uptake in the thigh of the fractured side.

Figure 11 Correlation of isotope uptake ratio (counts/g bone tissue) femoral head/trochanteric biopsy and femoral head ratio of preoperative scintimetry for 20 patients.



Satisfactory correlation between the biopsy ratio and the femoral head ratio of the preoperative scintimetry was found (Figure 11). With the specific activity of the femoral head biopsy equal to that of the trochanteric biopsy, a scintimetric femoral head ratio of about 1.50 may be expected and with absence of femoral head biopsy activity, a femoral head ratio below 0.70 in the preoperative scintimetry.

Figure 12 Correlation of isotope uptake ratio (counts/g bone tissue) femoral head/trochanteric biopsy and ratio of simultaneously performed tetracycline labeling for 17 patients.



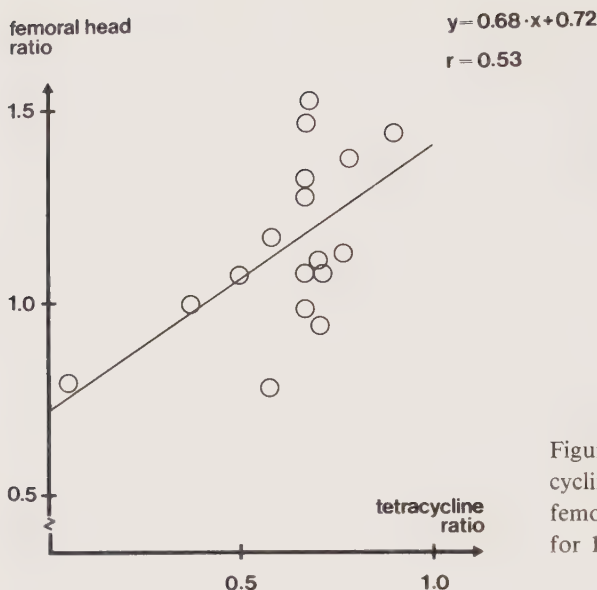


Figure 13 Correlation of preoperative tetracycline labeling value and preoperative femoral head isotope uptake in scintimetry for 17 patients.

E. Correlation of tetracycline labeling and Tc-MDP scintimetry

In 17 of the patients in III.D:2c, administration of 500 mg of oxytetracycline was carried out within two hours from Tc-MDP injection, i.e. before operation. The correlation of tetracycline values and isotope activity of the biopsies was good (Figure 12). From the equation of the regression line a numerical conformity between tetracycline values and biopsy scintimetry ratios could be deduced.

The correlation of tetracycline labeling and the preoperative scintimetric femoral head ratio (Figure 13) was less obvious but still significant.

F. Statistical methods

The chi-square test and Student's t- test were used as well as Wilcoxon's rank sum test.

The following levels of significance were used:

***	$p < 0.001$	highly significant
**	$0.001 < p < 0.01$	significant
*	$0.01 < p < 0.05$	almost significant
(-)	$0.05 < p$	not significant

IV Postoperative scintimetric observations

A. Femoral head vitality in uncomplicated healing

In the three year series, 20 of the 39 patients had an uneventful healing course clinically as well as radiographically; five had undisplaced and 15 displaced fractures (Table 2). Of these, 12 were followed up 36 months, three died without signs of complications before 24 months and three before 36 months. After 8 and 24 months, respectively, the remaining two patients were asymptomatic and regarded further examinations unnecessary. Both were interviewed at 36 months and denied hip problems.

Table 2 Correlation of fracture displacement according to Garden and healing course for the 39 patients in the three-year study.

	Fracture displacement			Total
	Garden	Garden	Garden	
	I—II	III	IV	
Normal healing	5	5	10	20
Redisplacement/non-union	1	3	6	10
Segmental collapse	1	3	5	9
Total	7	11	21	39

The mean femoral head uptake $\pm$ SD in the first 2—20 days postoperative scintimetry was 1.56 ± 0.62 (Table 3). After four months, the uptake had increased to 1.82 and after eight months it had decreased to 1.49. At subsequent investigations a steady decrease was seen with an uptake ratio of 1.12 at 36 months (Table 3, Figures 14, 15). The mean value for undisplaced fractures was highest in the first postoperative investigation, while for displaced fractures, it was highest at four months.

No reoperations were required in this group.

Table 3 Mean femoral head uptake ratio $\pm$ SD at consecutive scintimetric examinations in three-year study. Statistical significance of difference of uptake ratio refers to comparison with the group of normal healing (Student's t-test), n = number of patients investigated, uc = uncorrected and c = soft tissue corrected ratios. Figures within brackets denote range.

Months postop.		0-1		4		8		12		24		36	
Normal healing		n	20	20	20	20	20	19	12	16	12	12	12
		uc	1.56 $\pm$ 0.62 (0.45-3.03)	1.82 $\pm$ 0.39 (1.25-2.57)	1.49 $\pm$ 0.32 (1.12-2.26)	1.36 $\pm$ 0.24 (1.05-1.86)	1.17 $\pm$ 0.21 (0.95-1.85)	1.12 $\pm$ 0.25 (0.89-1.73)	1.21 $\pm$ 0.32 (0.83-1.98)	1.25 $\pm$ 0.31 (0.89-1.99)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)
		c	1.73 $\pm$ 0.92 (0.31-3.76)	2.19 $\pm$ 0.66 (1.26-3.39)	1.67 $\pm$ 0.46 (1.07-2.50)	1.48 $\pm$ 0.35 (1.00-2.05)	1.25 $\pm$ 0.31 (0.89-1.99)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)	1.21 $\pm$ 0.32 (0.83-1.98)
Redisplacement/ non-union		n	10	7	6	6	4	1	1	1	1	1	1
		uc	0.75 $\pm$ 0.13*** (0.59-0.98)	1.55 $\pm$ 0.34(-) (0.83-1.88)	1.57 $\pm$ 0.46(-) (0.96-2.11)	1.54 $\pm$ 0.22(-) (1.30-1.80)	1.94(***)	1.94(***)	1.94(***)	1.94(***)	1.94(***)	1.94(***)	1.94(***)
		c	0.67 $\pm$ 0.15** (0.39-0.85)	1.78 $\pm$ 0.64(-) (0.64-2.45)	1.79 $\pm$ 0.69(-) (0.69-2.47)	1.50 $\pm$ 0.27(-) (1.55-2.18)	2.51(***)	2.51(***)	2.51(***)	2.51(***)	2.51(***)	2.51(***)	2.51(***)
Segmental collapse		n	9	9	9	9	9	6	1	6	1	1	1
		uc	0.70 $\pm$ 0.14*** (0.51-0.94)	1.50 $\pm$ 0.64(-) (0.87-3.03)	1.65 $\pm$ 0.55(-) (0.92-2.45)	1.83 $\pm$ 0.70* (0.94-2.71)	2.72 $\pm$ 1.15*** (1.23-4.32)	3.35(***)	3.35(***)	3.35(***)	3.35(***)	3.35(***)	3.35(***)
		c	0.60 $\pm$ 0.16** (0.36-0.86)	1.67 $\pm$ 0.85(-) (0.64-3.51)	1.83 $\pm$ 0.70(-) (0.76-2.69)	2.05 $\pm$ 0.76* (0.94-3.04)	3.38 $\pm$ 1.97*** (1.33-7.07)	4.09(***)	4.09(***)	4.09(***)	4.09(***)	4.09(***)	4.09(***)

B. Femoral head vitality in redisplacement/non-union

Three fractures showed redisplacement within two months from the operation and one within four months. In two, non-union was evident at eight months, and in another three at 12 months. For one fracture where healing was difficult to assess, the diagnosis of non-union could not be confirmed with certainty until 24 months postoperatively.

In all, ten fractures developed redisplacement/non-union, one initially undisplaced and nine displaced (Table 2). The mean femoral head uptake $\pm$ S.D. in the first 6—17 days postoperative investigation was 0.75 ± 0.13 (Table 3). At four months the uptake was 1.55 and it remained at this level at 8 and 12 months (Figure 14). The difference from normal healing was highly significant ($p < 0.001$) at the first postoperative examination and not significant during the following year.

Hip arthroplasty was performed in the four patients with early redisplacement and in three patients with non-union. Nail extraction was performed in an immobile patient and the remaining two patients deteriorated beyond therapy.

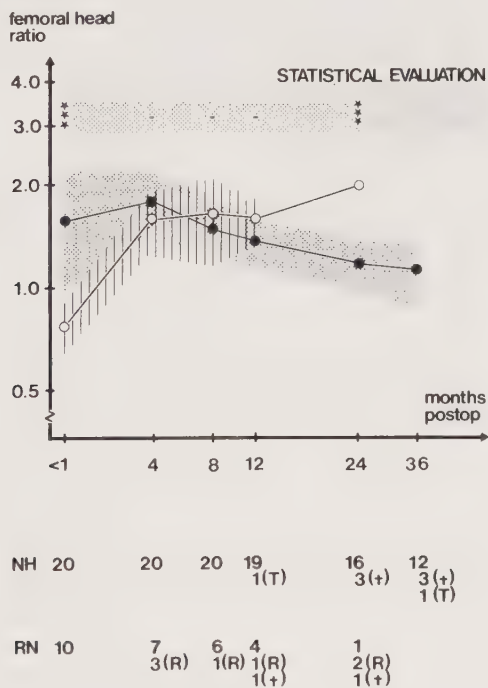


Figure 14 Scintimetry study. Mean femoral head uptake ratio $\pm$ SD in normal healing (NH [stippled]) and redisplacement/non-union (RN [dotted]). Above is shown statistical significance of differences between the groups. Figures below denote number of patients investigated. † = dead or deteriorated, R = reoperated (arthroplasty), T = discontinued clinical examination but reported asymptomatic after 36 months.

C. Femoral head vitality in segmental collapse

Segmental collapse developed in nine fractures which all had healed. Radiographic collapse was evident in two fractures at eight months, in another four at 12 months and in the remaining three at 24 months; one fracture was initially undisplaced and eight displaced (Table 2).

The mean femoral head uptake $\pm$ S.D. in the first 7—16 days postoperative scintimetry was 0.70 ± 0.14 (Table 3). At four months the uptake had increased to 1.50 and it increased further with each investigation although with a wide range (Figure 15). The difference from normal healing was highly significant ($p < 0.001$) at the first postoperative investigation and at 24 months.

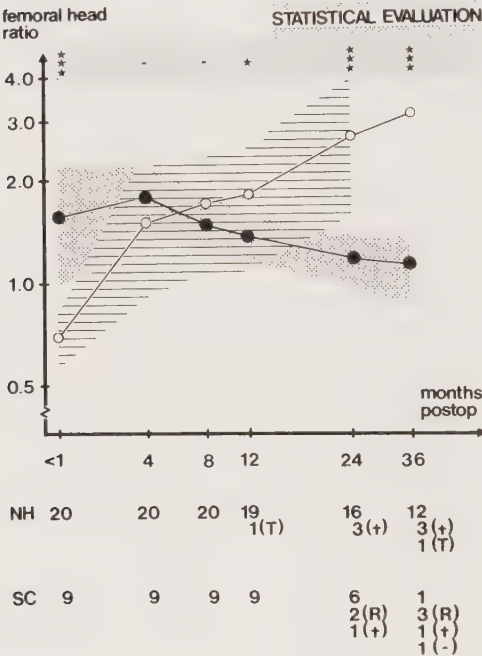


Figure 15 Scintimetry study. Mean femoral head uptake ratio $\pm$ SD in normal healing (NH ) and segmental collapse (SC ). See Figure 14 for explanation of symbols.

Four patients with segmental collapse have had hip arthroplasty, two have died and the remaining three were fairly asymptomatic 36 months from the primary operation.

D. Prognostic value of femoral head vitality determination

In the three-year series (II.B), the femoral head ratio in the scintimetry performed 2—20 days after operation was >1.0 in 19 patients who had uncomplicated healing (Table 4, Figure 16). For 20 patients this ratio was ≤ 1.0 ; 19 of these developed redisplacement/non-union or segmental collapse (Table 4). One patient (ratio 0.45)

Table 4 Clinical and radiographic results for 39 patients in three year study related to femoral head ratio in postoperative (2—20 days) scintimetry.

	Normal healing	Redisplacement/ non-union		Segmental collapse		Total
		reop	not reop	reop	not reop	
Ratio ≤ 1.0	1	8	2	4	5	20
Ratio > 1.0	19	—	—	—	—	19
Total	20	8	2	4	5	39

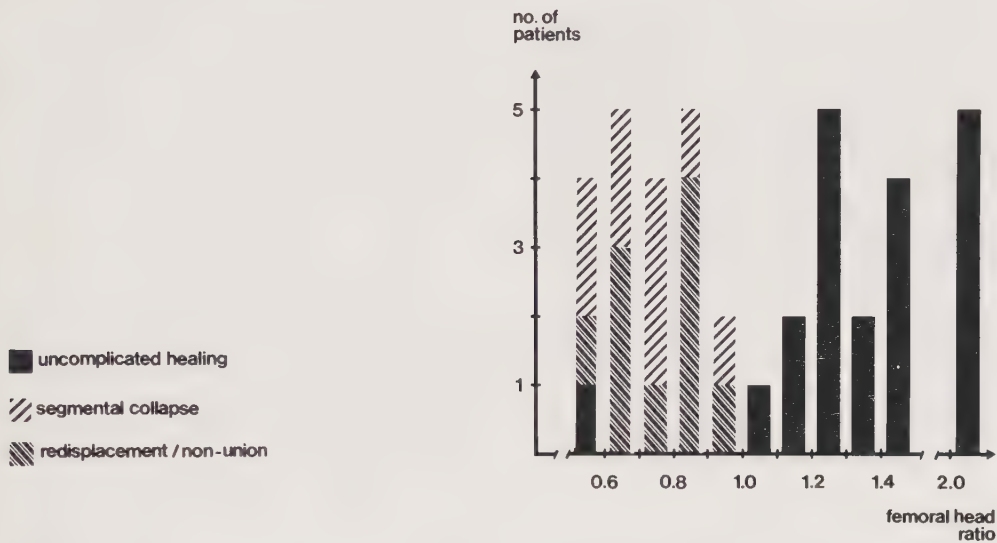


Figure 16 Femoral head activity for 39 patients at the first 2—20 days postoperative scintimetry.

showed no signs of healing complications at 36 months. The scintimetry for this patient was carried out only two days after the operation which was earlier than for the remaining patients of the study.

Scintimetry within three weeks of the operation was performed in 326 fractures. In 52 of these, healing complications have been diagnosed, redisplacement/non-union in 35 and segmental collapse in 17. One of these had a femoral head ratio of 1.21, the remaining 51 had a ratio ≤ 1.0 (Table 5).

For prognostic purpose, a scintimetry performed 1—3 weeks after operation seemed appropriate, deficient femoral head uptake predicting healing complications, and normal or increased uptake predicting normal healing.

Table 5 Femoral head uptake ratio <3 weeks after operation in 52 fractures with healing complications diagnosed in all 326 fractures subjected to postoperative scintimetry.

	Redisplacement/ non-union	Segmental collapse	Total
Ratio ≤ 1.0	34	17	51
Ratio > 1.0	1	—	1

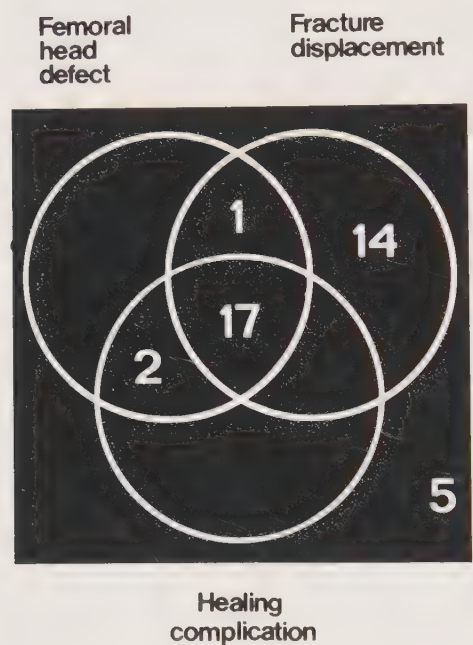


Figure 17 Relation between femoral head isotope defect, fracture displacement and the development of healing complications in 39 patients followed for three years.

The co-variation of postoperative uptake defect, healing complication and fracture displacement is shown in Figure 17 for the three-year series.

E. Transition from hypo- to hypermetabolism

Defined as a femoral head ratio ≤ 1.0 , femoral head hypometabolism was seen in post-operative (<3 weeks) examinations of 24 fractures also examined at four months. Three of these fractures were undisplaced and 21 displaced.

At the four months control five of these 24 fractures still had uptake defects, ratio range 0.68—0.94, one undisplaced and four displaced fractures. The remaining 19 fractures all had shifted to increased uptake, ranging from 1.10 to 3.03 (Figure 18).

In order to obtain closer knowledge of the time table for this transition, scintimetry was performed 6—8 weeks after the operation in eight fractures with primarily low

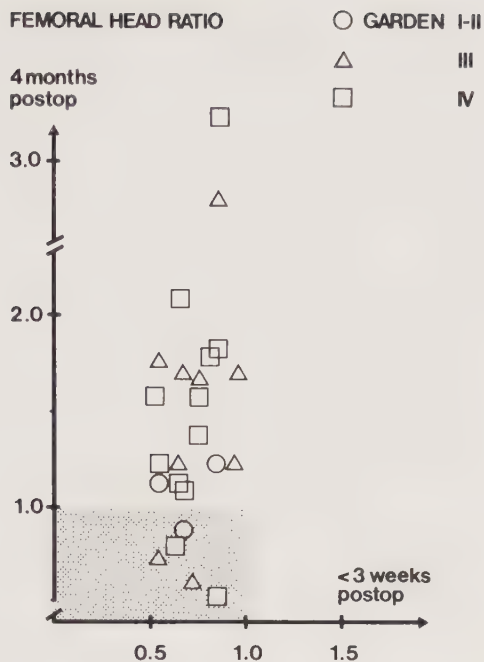


Figure 18 Comparison of femoral head uptake in scintimetry within three weeks from operation and four months from operation in 24 fractures with postoperative uptake defects. ○ = Garden I—II fracture, △ = Garden III fracture, □ = Garden IV fracture.

ratios (0.52—0.98); one was undisplaced and seven fractures were displaced. Six to eight weeks after the operation only one, a displaced fracture, still had a decreased femoral head ratio, 0.88; the others now had ratios between 1.19 and 2.38 (Figure 19).

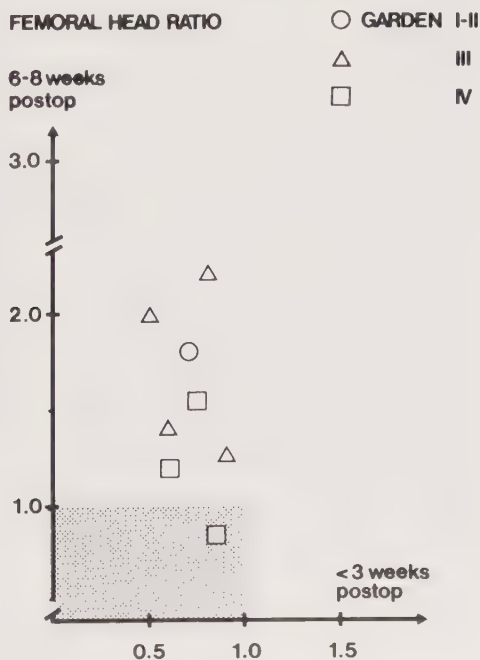


Figure 19 Comparison of femoral head scintimetry within three weeks from operation and six—eight weeks from operation in eight fractures with postoperative uptake defects. See Figure 18 for explanation of symbols.

Two of the patients with deficient activity at four months were followed further. Both still had deficient activity at eight months but at 12 months they had increased ratios, 1.33 and 1.62, and healing complications were now evident in both.

Transition from hypo- to hypermetabolism thus occurred early in the postoperative course for the majority of fractures and preceded the development of clinical and radiographic evidence of healing complications.

F. Femoral head/shaft ratio

Bilaterality in femoral neck fracture frequently makes the femoral head ratio unsuitable for pro- and diagnostic purpose as does other contralateral hip disease.

To evaluate the possibility of making a prognostic estimation at the first postoperative scintimetry in those with contralateral hip disease, ratios femoral head/shaft uptake per picture element on the fracture side of patients in II.B were correlated to the femoral head ratio (Figure 20); the correlation coefficient was 0.91. All fractures with a head/shaft ratio < 1.40 had femoral head ratios ≤ 1.0 while a head/shaft ratio > 1.40 was noted for 19 normally healing fractures with femoral head ratios > 1.0 plus one with a femoral head ratio of 0.98 which developed non-union.

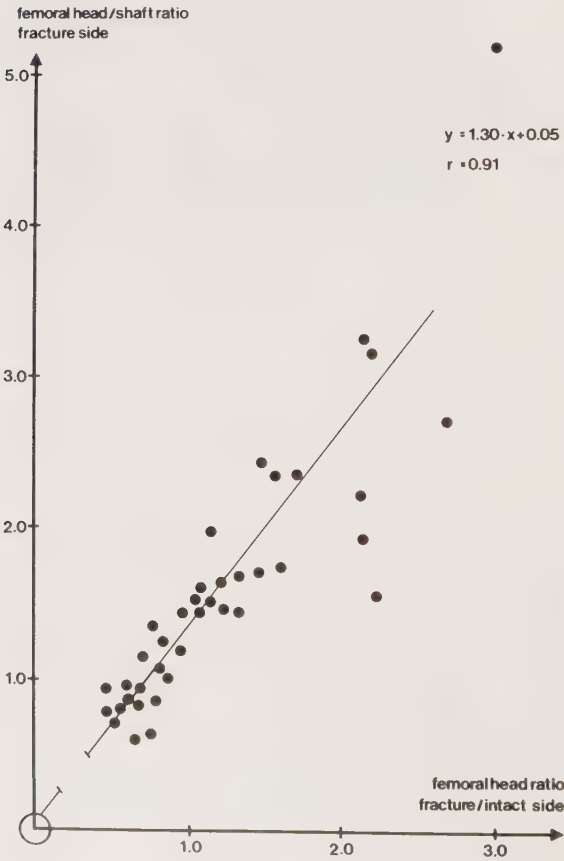


Figure 20 Scintimetry study. Correlation of femoral head/shaft ratio on the fracture side and femoral head ratio at the first postoperative examination for 39 patients.

V Comparison between pre-, per- and postoperative femoral head vitality

An undisplaced fracture had a preoperative scintimetric femoral head ratio of 1.08, followed by a postoperative femoral head uptake defect and a ratio 0.58 (Figure 21). With this background, the effect on femoral head vitality of the operation was studied.

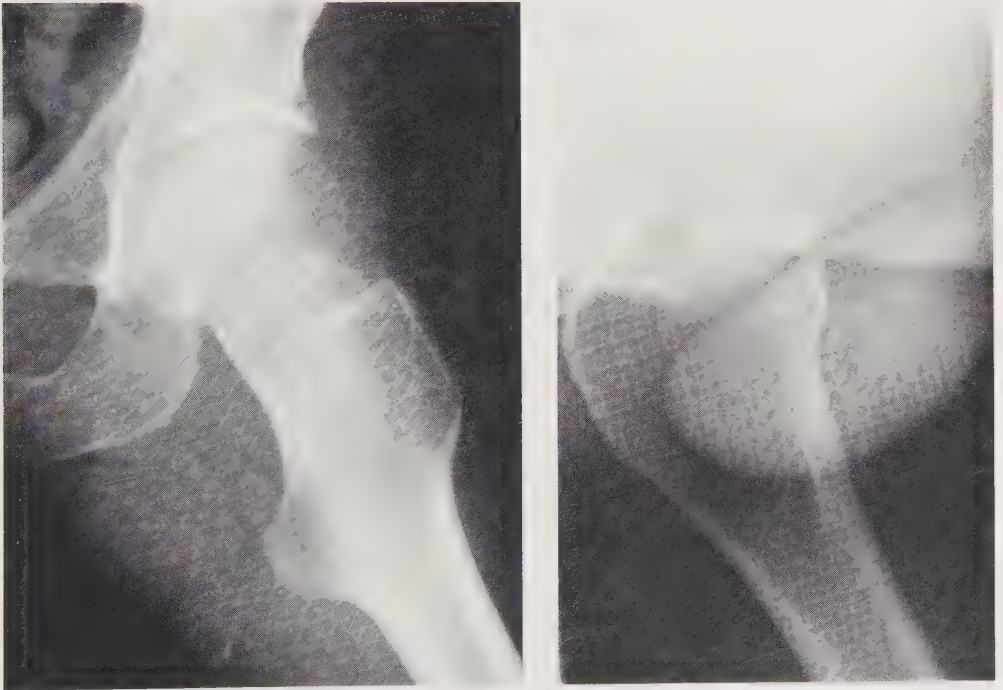


Figure 21 a Minimally displaced femoral neck fracture of 43-year old male.

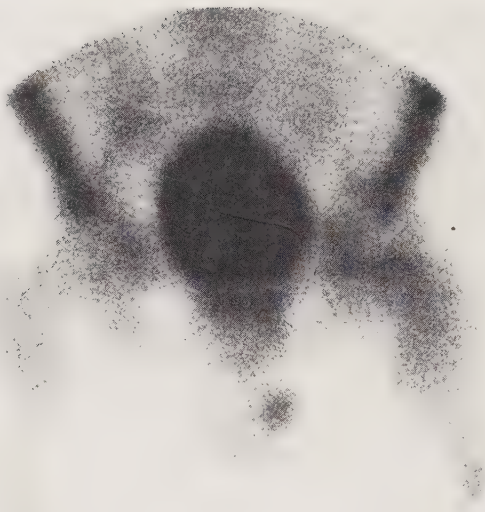


Figure 21 b Preoperative scintimetry of fracture of Figure 21 a. Femoral head ratio = 1.08.

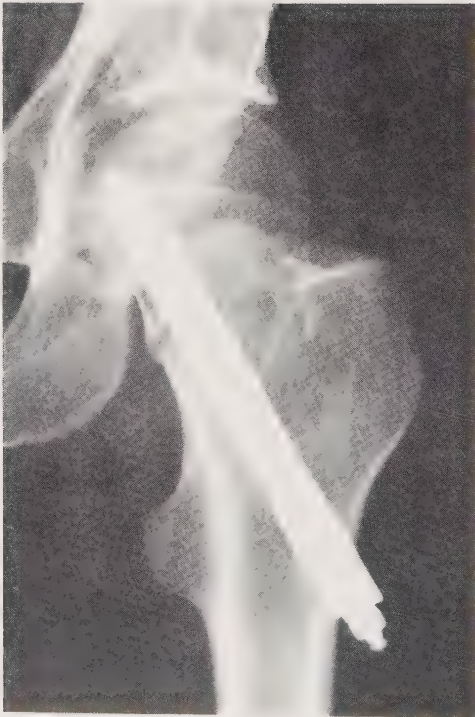


Figure 21 c Radiographic appearance after nailing without fracture reduction.



Figure 21 d Scintimetry eight days after nailing of fracture of Figure 21 a. Femoral head ratio = 0.58.

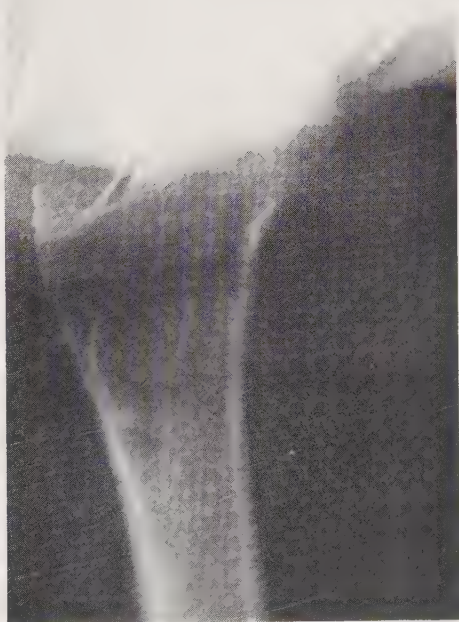


Figure 21 e Radiographic appearance 24 months after nailing. Nail extraction has been performed. Segmental collapse of the femoral head is evident but clinical symptoms were minor.

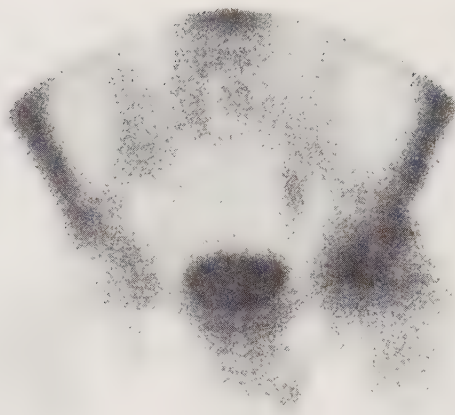


Figure 21 f Scintimetry performed 24 months after nailing of fracture of Figure 21 a. Hypermetabolism is noted over the femoral head, ratio = 2.65.

A. Pre- versus postoperative femoral head vitality

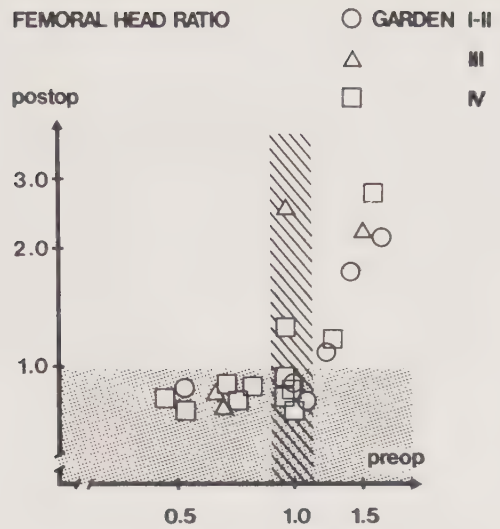
The mean pre- and postoperative ratios for 22 fractures investigated (II.C) were 0.95 and 1.09 (Table 6), for undisplaced fractures 1.10 and 1.14, for Garden III fractures 1.07 and 1.13, and for Garden IV fractures 0.84 and 1.05.

All six fractures with preoperative ratios >1.10 had an intact femoral head uptake postoperatively (Figure 22). All eight fractures with definite uptake defects preoperatively, ratio <0.90 , also had defective postoperative uptake. The remaining eight fractures had intermediate femoral head ratios preoperatively between 0.90 and 1.10. Of these, two had increased ratios postoperatively, while the remaining six had defective uptake. Two of the latter six fractures were undisplaced.

Table 6 Mean femoral head uptake ratio $\pm$ SD in 22 patients subjected to scintimetry before and one—two weeks after operation.

		Garden classification			Total
		I—II	III	IV	
	n	6	4	12	22
Mean femoral ratio $\pm$ SD (range)	Preop	1.10 $\pm$ 0.34 (0.54—1.54)	1.07 $\pm$ 0.29 (0.74—1.45)	0.84 $\pm$ 0.28 (0.46—1.44)	0.95 $\pm$ 0.31 (0.46—1.54)
	Postop	1.14 $\pm$ 0.58 (0.58—2.04)	1.13 $\pm$ 0.56 (0.63—2.13)	1.05 $\pm$ 0.73 (0.53—2.70)	1.09 $\pm$ 0.67 (0.53—2.70)

Figure 22 Scintimetry study. Femoral head ratio preoperatively compared to one-two weeks postoperatively in 22 patients. See Figure 18 for explanation of symbols.



6/22

For ~~8/22~~ fractures it seemed likely that the operation had impaired the femoral head vitality and thus the healing prognosis.

B. Effect on femoral head vitality of fracture reduction

With the results of V.A the likelihood of additional vascular trauma being inflicted by the operation seemed proven. By comparison of pre- and peroperative (after reduction, before nailing) femoral head vitality by tetracycline labeling, the effect of fracture reduction was investigated.

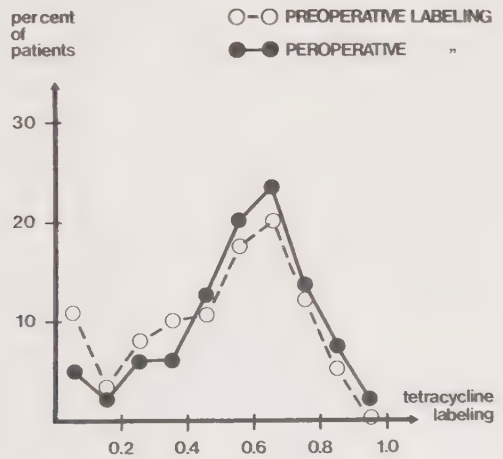


Figure 23 Tetracycline study. Percentual distribution of tetracycline labeling values in preoperative group ——— (n = 63) and peroperative group ——— (n = 307).

Table 7 Mean tetracycline labeling values $\pm$ SD after pre- and peroperative tetracycline administration.

	Tetracycline labeling			
	Preoperatively		Peroperatively	
	n	Mean value	n	Mean value
Garden I—II	14	0.56 ± 0.22	89	0.65 ± 0.23
Garden III	17	0.47 ± 0.23	70	0.50 ± 0.19
Garden IV	32	0.47 ± 0.26	148	0.52 ± 0.22
Total	63	0.48 ± 0.23	307	0.54 ± 0.21

The mean femoral head/trochanter ratio in the preoperative labeling group was 0.48 ± 0.23 , and the corresponding value for peroperative labeling was 0.54 ± 0.21 ($p > 0.05$) (Table 7). The distribution of patients according to labeling ratios was almost identical in the two groups (Figure 23), and correlation with initial displacement likewise did not reveal any difference (Table 7).

In the total material, undisplaced fractures had higher ** mean labeling values than displaced fractures while no difference was noted comparing Stage III and IV fractures.

Eleven patients were below 50 years of age, four with undisplaced fractures, four with Stage III and three with Stage IV fractures. In spite of this relatively fortunate displacement distribution, these patients had a lower ** tetracycline mean value, 0.35 ± 0.26 , than the total material of 0.52 ± 0.20 .

Fracture reduction thus did not seem to impair the circulatory state of the femoral head.

VI Comparison of the effects of nail and pins on femoral head vitality

The vascular trauma to the femoral head added by the operation was concluded to occur by the osteosynthesis procedure rather than by reduction of the fracture. A method of osteosynthesis, originally developed for nailing of the slipped capital femoral epiphysis (Hansson 1975, 1982), was compared to the routine method of the department, the four-flanged nail (Rydell 1964).

The channel for the core of the four-flanged nail is predrilled while the flanges are prepared for with a punch and the nail is hammered in. The channel for the hook-pin is also predrilled, but it has no flanges, and the hook is inserted with a screw mechanism to minimize the operative trauma (Figure 24).

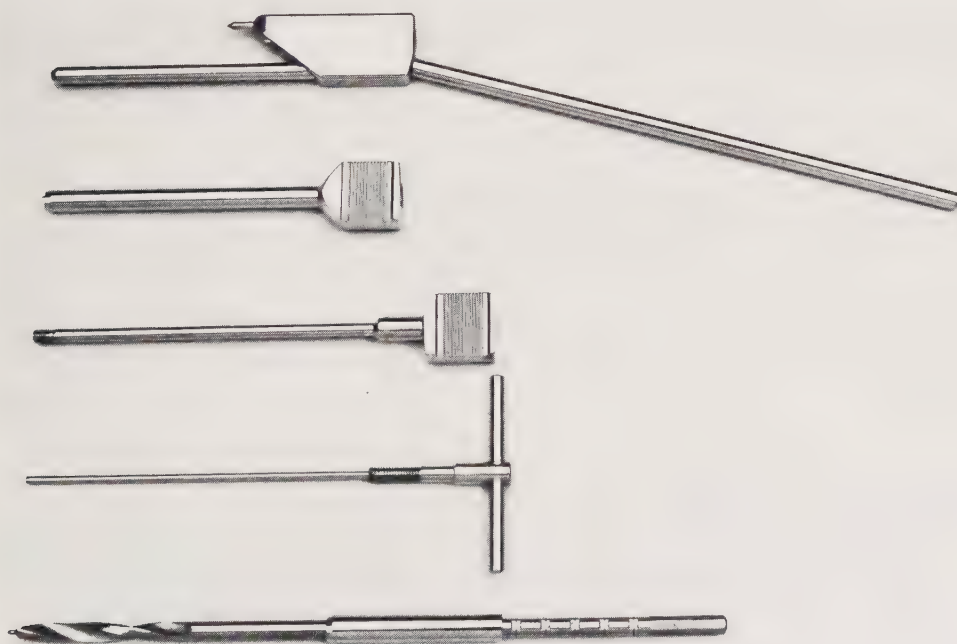


Figure 24 Insertion instruments for Hansson hook-pins.

Table 8 Peroperative tetracycline labeling ratios and postoperative femoral head scintimetry ratios in osteosynthetic comparison study. Significance of difference (Student's t-test) between the groups is noted.

		n	Perop tetracycline ratio. Mean $\pm$ SD	Postop scintimetry ratio. Mean $\pm$ SD
Four-flanged nail	Undisplaced fractures	16	0.66 $\pm$ 0.12	1.52 $\pm$ 0.20
	Displaced fractures	21	0.54 $\pm$ 0.14	0.96 $\pm$ 0.23
Hook-pins	Undisplaced fractures	45	0.67 $\pm$ 0.12(—)	1.84 $\pm$ 0.19***
	Displaced fractures	52	0.52 $\pm$ 0.13(—)	1.22 $\pm$ 0.35***

For the 134 fractures compared in this part of the study (II.E), preosteosynthetic vitality was determined by peroperative tetracycline labeling, and postoperative vitality by scintimetry at 7—14 days.

A. Peroperative femoral head vitality

No difference was observed between nailed and pinned fractures as regards the preosteosynthetic circulatory state of the femoral head, determined by peroperative tetracycline labeling (Table 8).

B. Postoperative femoral head vitality

In undisplaced fractures the mean postoperative femoral head ratio for the pin group was higher ***, 1.84 $\pm$ 0.19, than for the nail group, 1.52 $\pm$ 0.20. In displaced fractures, also, the mean ratio was higher ***, 1.22 $\pm$ 0.35 for the pin group than for the nail group, 0.99 $\pm$ 0.23 (Table 8).

In undisplaced fractures, decreased postoperative vitality with scintimetry ratio $\leq$ 1.0, was noted in 3/16 operated with the nail and in 3/21 with pins (Table 9). In dis-

Table 9 Postoperative femoral head isotope uptake of undisplaced fractures for patients in osteosynthetic comparison study.

	Femoral head ratio		Total
	$\leq$ 1.0	$>$ 1.0	
Four-flanged nail	3	13	16
Hook-pins	3	18	21
Total	6	31	37

Table 10 Postoperative femoral head isotope uptake of displaced fractures for patients in osteo-synthetic comparison study.

	Femoral head ratio		Total
	≤1.0	>1.0	
Four-flanged nail	33	12	45
Hook-pins	23	29	52
Total	56	41	97

placed fractures, decreased postoperative vitality for those nailed was noted in 33/45 and for those pinned in 23/52 (Table 10). Using the chi-square test a significant difference was noted (chi-square = 7.40) and this significance was at hand if ratios above and below 0.80 or 0.90 were compared also (Figure 25). According to Wilcoxon's rank sum test the difference was almost significant (p = 0.02).

According to the criteria in IV.D, healing complications are to be expected in 36 of 61 operated on with the nail and 26 of 73 with pins.

Following the comparative study, one year of hook-pinning only (II.F) yielded two femoral heads with deficient uptake in 32 undisplaced fractures and 23 in 97 displaced fractures. With these fractures included, primary postoperative scintimetry had been performed in 326 fractures, 124 nailed and 202 pinned. Decreased femoral head vitality in undisplaced fractures was seen for 27 per cent in the nail group and 9 per cent in the pin group. In displaced fractures, 66 per cent in the nail group and 31 per cent in the pin group had decreased vitality (Table 11) and thus belonged to the risk group destined for healing complications.

Figure 25 Femoral head uptake ratio in postoperative scintimetry for 97 patients with displaced fractures, 45 operated on with the four-flanged nail and 52 with the hook-pins. Results of the statistical evaluation by the chi-square test are shown.

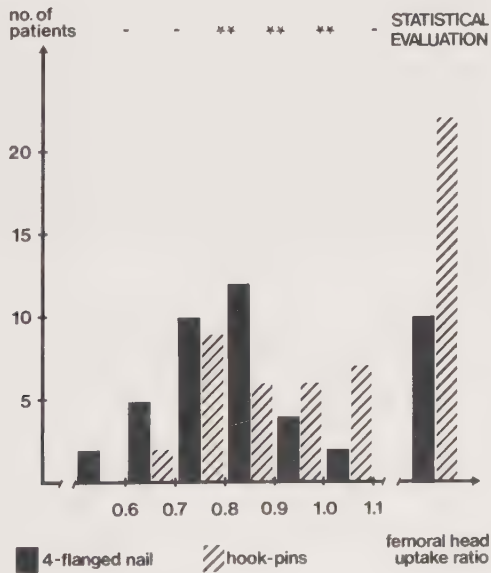


Table 11 Postoperative scintimetric femoral head vitality for 326 fractures, 124 nailed and 202 pinned.

	Femoral head ratio		Fraction with ratio ≤ 1.0
	≤ 1.0	> 1.0	
<i>Undisplaced fractures</i>			
Four-flanged nail	8	22	.27
Hook-pins	5	48	.09
<i>Displaced fractures</i>			
Four-flanged nail	62	32	.66
Hook-pins	46	103	.31
<i>Total</i>			
Four-flanged nail	70	54	.56
Hook-pins	51	151	.25

C. Clinical and radiographic follow-up

All but six of 134 patients in II.E were followed-up clinically and radiographically at four and twelve months or until death or reoperation.

Of 16 undisplaced fractures operated with the nail (Table 12), 13 were free from complications at one year. One patient had pronounced fracture displacement at four months and had an arthroplasty. One patient died, and one was lost to follow-up. Of 21 pinned undisplaced fractures, 15 were free from complications, and six died within one year (Table 12).

Table 12 Clinical and radiographic one year follow-up of undisplaced fractures in osteosynthetic comparison study. Figures within brackets denote decreased femoral head uptake.

	No complication	Complication reop	Dead	No follow-up	Total
Four-flanged nail	13 (2)	1 (1)	1 (—)	1 (—)	16 (3)
Hook-pins	15 (2)	—	6 (1)	—	21 (3)
Total	28 (4)	1 (1)	7 (1)	1 (—)	37 (6)

Among 45 displaced fractures operated with the nail (Table 13), 14 had no complications. Fourteen fractures had redisplacement/non-union; 12 of these had been reoperated. Three patients had segmental collapse; one of these had been scheduled for hip arthroplasty and two were rather asymptomatic. Eleven patients had died and three were lost to follow-up.

Of 52 pinned displaced fractures, 31 had no complications. Six patients had developed redisplacement/non-union, three of whom had been reoperated. Two patients had segmental collapse with minor symptoms, 11 had died and two were lost to follow-up.

Table 13 Clinical and radiographic one year follow-up of displaced fractures in osteosynthetic comparison study. Figures within brackets denote decreased femoral head uptake.

	No compli- cation	Complication			Dead	No follow- up	Total
		Redisplacement/ non-union reop	not reop	Segmental collapse not reop			
Four-flanged nail	14 (8)	12 (12)	2 (2)	3 (3)	11 (6)	3 (2)	45 (33)
Hook-pins	31 (10)	3 (3)	3 (2)	2 (2)	11 (6)	2 (—)	52 (23)
Total	45 (18)	15 (15)	5 (4)	5 (5)	22 (12)	5 (2)	97 (56)

A total of 16 patients were reoperated within one year, 13 in the nail group and three in the pin group. Another five in each group had radiographic signs of complications. Twenty-five of these 26 patients had deficient femoral head vitality postoperatively.

Table 14 Number of fractures in nail and pin groups in whom redisplacement and/or non-union were diagnosed at 12 months or earlier and number of patients with deficient femoral head uptake in scintimetry one—two weeks after the operation.

	Redisplacement/ non-union	Femoral head ratio ≤ 1.0
Four-flanged nail	15	36
Hook-pins	6	26
Total	21	62

Redisplacement/non-union developed within a year from fracture in 15 nailed fractures while the final number of complications among those nailed according to postoperative scintimetry would amount to 36 (Table 14). Six pinned fractures, including one with retained postoperative vitality, had redisplacement/non-union within a year; the total number of expected healing complications in this group was 26. The tendency for the pin group to develop fewer early complications than the nail group in relation to the number of defective femoral heads might be ascribed to a better mechanical stability of fracture fixation by the two hook-pins.

The outcome during the first postoperative year corresponded well to the scintimetric prediction and also to that observed in the three-year series.

VII Discussion

A. Material

The aim of the present investigation was to evaluate the diagnostic and prognostic use of femoral head vitality determination in fracture of the femoral neck, and its consequences for the therapeutic approach. The composition of the patient material regarding age, sex and fracture displacement was comparable to that of previous investigations (Alffram 1964, Öhman et al 1969, Barnes et al 1976, Ceder 1980), and from January 1981 it comprised every patient admitted for femoral neck fracture in Lund.

Femoral neck fractures in patients below 50 years of age yield a higher complication frequency (Askin & Bryan 1976, Barnes et al 1976, Zetterberg et al 1982), and in the present study this was reflected in a significantly lower tetracycline labeling ratio for this group of patients. The probable explanation is that the fracture-producing trauma is greater for this category (Askin and Bryan 1976, Protzman and Burkhalter 1976).

Femoral head vitality was significantly better for undisplaced fractures than for displaced fractures irrespective of time and method of determination. This would be expected with the lower complication rate reported (Frangakis 1966, Massie 1973, Barnes et al 1976, Thorling 1980). Between Garden Stage III and IV fractures no significant differences were observed. Barnes et al (1976) and Högh et al (1982) found comparable rates of healing complications for Stage III and IV fractures while Brown and Abrami (1964) and Kofoed and Alberts (1980) noted higher rates for Stage IV fractures. The reason for this disagreement may be the inexactness of the Garden classification noted by Brown and Abrami (1964). Varus angulation of the fracture is generally believed to be more injurious to the femoral head vascularization than valgus angulation, while the degree of angulation seems less important; displacement may have been more pronounced at the moment of fracture (Hulth 1956).

B. Methods

1. Tetracycline labeling

The tetracycline labeling uptake ratios presented here describe the bone vitality only in the region where the biopsy was taken which might not always be representative for the

entire femoral head (Hulth 1961, Sevitt 1964, Catto 1965). However, tetracycline deposition in core biopsies and ^{99m}Tc sulphur-colloid scintimetry have been shown to correlate well (Meyers et al 1977), and measurements of the tetracycline label in entire femoral heads agree with the core biopsy (Strömqvist et al 1981). These results plus the fact that the femoral head biopsy is achieved from a channel transversing the center of the femoral head make the method dependable for estimation of the viability of the femoral head.

By means of preoperative tetracycline labeling Rokkanen and Slätis (1974) concluded that ischaemic changes of the femoral head occur in every femoral neck fracture. The present investigation confirmed a very high incidence of femoral head labeling reduction compared to the trochanteric region; 97 per cent of the femoral heads had a reduction >10 per cent. Total absence of tetracycline on the other hand was very rare.

In previous studies tetracycline labeling of the femoral head has been determined as absent or present (Rokkanen and Slätis 1974, Stadalnik et al 1975, D'Ambrosia et al 1976, Lucie et al 1981). In this study a ratio was determined based on tetracycline distribution and intensity in multiple sections of a femoral head biopsy and related to the corresponding measurement of a trochanteric biopsy. Satisfactory quantification of labelling could be performed (Figure 6) and the method can be used in studies of pre- and peroperative vitality.

2. ^{99m}Tc -MDP scintimetry

After femoral neck fracture, technetium labelled phosphonates have been used for vitality determination and prognostics by D'Ambrosia et al (1976), Bauer et al (1980) and Greiff et al (1980) with a visual estimation of femoral head uptake. Numerical analysis as performed here should increase the precision and avoid the fallacy (Strömqvist et al 1983b) of underestimating femoral head activity when intense uptake in the fracture line is present. Correlation between visual and numerical evaluation was found satisfactory (Figure 9). Correction for soft tissue uptake did not appreciably change the general results of the study (Table 3).

Vascular investigations have been performed with labeled sulphur-colloid (Meyers et al 1977) and red blood cells (Kempi and Sandegård 1982). The failure to recognize 3/10 uptake defects in the vascular phase of the present study might be due to cellular damage in spite of retained vascularization.

The positioning of the femoral head within the acetabulum makes it difficult to produce an image of the femoral head alone; part of the emission derives from the acetabular walls. This may explain why an avascular head or a femoral head prosthesis (Figure 26) seldom has a ratio <0.50. Comparison between the uptake ratio of femoral head biopsy/trochanteric biopsy and the routinely used femoral head ratio seems to underline this (Figure 11). Emission tomography (Strömqvist et al 1983a) may disclose deficient femoral head uptake behind hyperactive acetabular walls (Figure 27) as well as local uptake defects within the femoral head.



Figure 26 ^{99m}Tc -MDP scintimetry eight months after uncomplicated arthroplasty of the right hip; the contralateral hip was normal. Femoral head ratio prosthetic/intact side was 0.52.



Figure 27 a Displaced femoral neck fracture of 45-year old male.



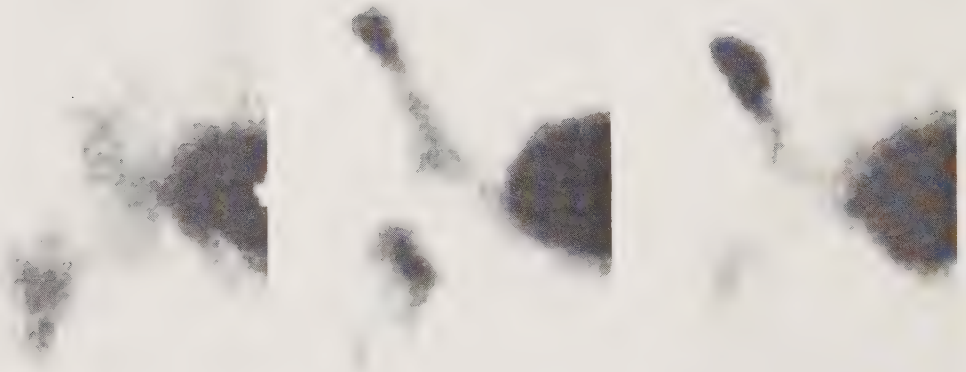
Figure 27 b Radiographic appearance of fracture of Figure 27 a after closed reduction and osteo-synthesis with two hook-pins.



Figure 27 c Scintimetry ten days after the operation. Femoral head ratio = 0.67.



Figure 27 d Scintimetry performed four months after the operation for fracture of Figure 27 a. Femoral head ratio = 1.05 and has increased from the first postoperative investigation (Figure 27 c).



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Figure 27 e—g Emission tomography performed simultaneously with the image above. High isotope activity is noted corresponding to the anterior (left) and posterior (right) acetabulum but low activity centrally in the head of the femur (middle).

C. Prognostic value of scintimetry

Non-union of the femoral neck fracture is usually diagnosed radiographically within a year from fracture (Barnes et al 1976). For the development of segmental collapse, revascularization of the femoral head after fracture healing is required (Catto 1965, Glimcher and Kenzora 1979a). Radiographic evidence of segmental collapse is rare before six months and usually occurs during the second year (Barnes et al 1976, Brümmer 1983). About 80 per cent of the collapses exhibit radiographic changes within two years from fracture (Brown and Abrami 1964, Jacobs 1978, Calandruccio and Anderson 1980) and the majority of the remaining during the following year (Barnes et al 1976) although development as late as 17 years from fracture has been reported (Massie 1973).

Femoral head scintimetry 1—3 weeks after the operation was highly predictive as regards healing complications; ratios >1.0 indicated uncomplicated healing and ratios ≤ 1.0 complications (Figure 16). The only definite exception was a patient with a ratio of 0.45 without any signs of complications at three years. In this case, scintimetry was performed on the second postoperative day which was earlier than for the other patients; a transient benign ischaemia might be the explanation for the uptake defect. It seems recommendable to perform the prognostic scintimetry at 1—2 weeks.

Segmental collapse is generally regarded as mainly associated with vascular injury (Woodhouse 1962, Boyd and Calandruccio 1963, Hulth 1965) although mechanical factors have been proposed (Deyerle 1973, Arnoldi and Lemperg 1977, Thorling 1980). Concerning the pathogenesis of non-union, mechanical aspects have dominated (Scheck 1959, Massie 1973, Thorling 1980) although Tucker (1950), Johansson (1964) and Hulth (1965) have postulated vascular injury as most important. The results of this study clearly showed that vascular injury is the main pathogenic mechanism in redisplacement and non-union as well as in segmental collapse in femoral neck fracture. No difference in postoperative femoral head ratio was noted between redisplacement/non-union and segmental collapse. However, adequate fracture reduction is an obvious prerequisite; with the aid of biplane fluoroscopy and the extension operating table virtually all fractures can be reduced. Improper fracture treatment can usually not be expected to be compensated for by a satisfactory femoral head vitality.

A femoral head ratio >1.0 is consistent with uncomplicated healing though it should not be interpreted as undisturbed femoral head vascularization which is uncommon after femoral neck fracture (Sevitt 1964, Catto 1965, Rokkanen and Slätis 1974) but rather as retainment of vascularization and metabolism sufficient for fracture healing without risk for segmental collapse. It is to be expected that borderline cases must exist where the amount of anastomoses within the femoral head (Sevitt and Thompson 1965) and the direction of bone resorption and formation during revascularization (Sevitt 1964) may play an important role for the healing prognosis.

D. Dynamics of postoperative vitality

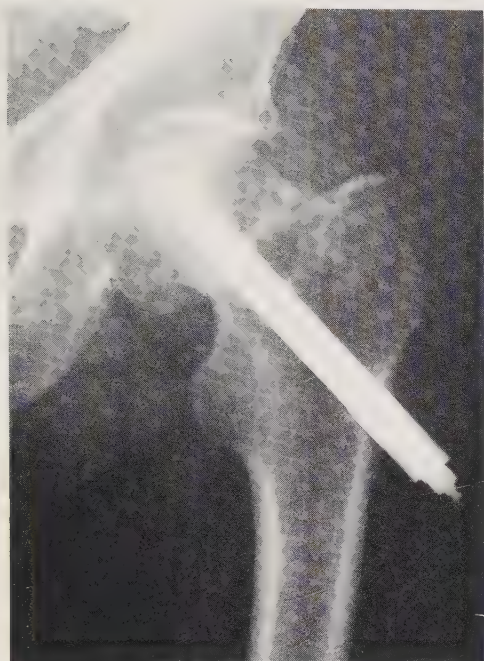
While normally healing fractures had a postoperative femoral head ratio > 1.0 , further increase after four months and thereafter a gradual decrease toward unity, those developing healing complications had a more varying course. From the postoperative uptake defect, the majority had increased uptake at four months (Figure 18) and even as early as 6—8 weeks after the operation in seven of eight fractures investigated (Figure 19). In two fractures, an uptake defect was recorded also at eight months, but the mean ratio for those developing non-union did not show the decrease seen in normal healing (Figure 14), and for those developing segmental collapse, like in ^{85}Sr -scintimetry (Asnis et al 1976), it steadily increased (Figure 15).

Transition from decreased to increased uptake, which did not improve the healing prognosis, may be an effect of varying degrees of partial necrosis as described by Sevitt (1964) and Catto (1965) with hyperactivity in the surrounding vital parts of the femoral head accreting enough tracer to compensate for avascular parts. Creeping substitution as described by Phemister (1920) is an extremely slow process (Charnley et al 1957) and could not explain these rapid uptake changes. In addition, emission tomography studies suggest the possibility of acetabular hyperactivity hiding a femoral head defect (Figure 27).

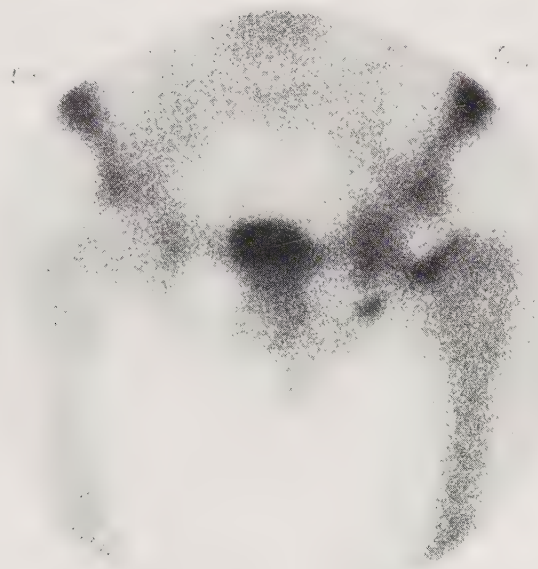
The scintimetric prediction of healing complications can thus be accomplished in the early postoperative course as a lower than normal uptake and from 24 months on as a higher than normal uptake. The low frequency of femoral head uptake defects noted by Greiff et al (1980) may be due to the fact that the isotope investigations were performed 6 and 11 weeks after fracture. Transition to hypermetabolism may already have occurred and with a long follow-up time, a higher complication rate can be encountered.

Radiographic identification of segmental collapse in every case was preceded by a femoral head and fracture line uptake increase in scintimetry, a phase of hypermetabolism identified by ^{85}Sr scintimetry (Asnis et al 1976, Brümmer et al 1982) and by $^{99\text{m}}\text{Tc}$ -DP scintimetry (Alavi et al 1977).

The possibility of union in spite of a necrotic femoral head was suggested already by Axhausen (1922) and has later been verified (Catto 1965, Bauer et al 1980, Sevitt 1981). It seems plausible that solid union and a dead femoral head with intact cartilage (Glimcher and Kenzora 1979a, b) would serve its function perfectly well, and that revascularization should be regarded as a threat in such a case. This is illustrated in the radiographic and scintimetric image (Figure 28) of a 51 year old painter 18 months after nailing of a femoral neck fracture. His femoral head ratio was 0.90 and except for local lateral hip symptoms, relieved after nail extraction, he was painfree. The theoretical background for the muscle pedicle grafting operation of Judet (1962) and Meyers et al (1973, 1980) which is performed at nailing or as a secondary procedure many months later (Meyers et al 1977) is not logical unless it be performed as an emergency before irreversible anoxic cellular damage has developed; i.e. within 6—12 hours from fracture (Woodhouse 1964).



a



b

Figure 28 Radiograph (a) and scintimetry (b) 18 months after nailing of a displaced left-sided femoral neck fracture in 51 year old male. Fracture healing without affection of the femoral head and deficient femoral head isotope uptake, ratio 0.90, are noted. After nail extraction for local lateral symptoms, the patients has remained asymptomatic through 48 months.

E. Effect of operative handling on femoral head vitality

The fracture moment has generally been regarded as the time of vascular injury (Phemister 1934, Massie 1973, Meyers et al 1977, Lucie et al 1981) although the extension operating table and the procedure of fracture reduction and osteosynthesis have been suggested as potential threats to the vascularization (Linton 1944, Hulth 1956, Lowell 1980).

Indirect proofs of the risk for peroperative circulatory injury are the findings of a higher frequency of femoral head necrosis in nailed than in untreated femoral neck fractures without displacement (Linton 1944, Ibsen 1951, Öhman et al 1969, Bentley 1980).

In the present tetracycline investigation, no difference between femoral head vitality before operation and after closed fracture reduction on the extension table was noted. Soto-Hall et al (1964) in humans and Calandruccio and Anderson (1980) in dogs have demonstrated a rise in intraarticular hip pressure on internal rotation of the hip, in the latter investigation enough to prevent perfusion of the femoral epiphysis. In the present study two cases with total absence of peroperative tetracycline labeling followed by a satisfactory femoral head ratio in the postoperative scintimetry were observed. On the contrary, restoration of arrested femoral head blood supply by femoral neck fracture reduction was demonstrated by Woodhouse (1962) and Müssbichler (1970) with oxygen tension measurement and arteriography, respectively. The findings presented here do not question any of these observations but they negate their quantitative significance. In eight of 22 fractures with pre- and postoperative scintimetry the postoperative femoral head ratio could not be predicted from the preoperative. Six fractures deteriorated from preoperative ratios about 1.0 to values 0.86 and lower, and two fractures increased to satisfactory ratios (Figures 21, 22).

This part of the study demonstrated the possibility that the operation could injure the femoral head vitality; the injury was probably associated with the nailing procedure (Strömqvist and Hansson 1982) as has been proposed in isolated cases by Linton (1944) and Sevitt (1981). Preoperative scintimetry after femoral neck fracture with ^{99m}Tc sulphur-colloid (Meyers et al 1977) or ^{99m}Tc phosphate (Lucie et al 1981) has correlated well with histologic evidence of necrosis of femoral heads removed at primary replacement arthroplasty. The prediction inaccuracy encountered in nailed fractures with clinical/radiographic follow-up in these two investigations has probably been due to failure to recognize the possibility of intraoperative vascular trauma as observed here. Prediction failures in invasive tracer studies with radio-iodine (Johansson 1964, Holmqvist and Alffram 1965) and radio-phosphate (Arden 1960, Boyd and Calandruccio 1963) also may be explained by the fact that these investigations were performed prior to the osteosynthetic procedure.

F. Effect of the osteosynthesis on femoral head vitality

Non-union is rare in fractures with minimum displacement and amounts to 20—30 per cent in displaced fractures (Banks 1962, Barnes et al 1976, Söreide et al 1979, Caland-

ruccio and Anderson 1980). Segmental collapse occurs in 10—20 per cent of fractures with minimum displacement and 15—35 per cent in displaced fractures (Banks 1962, Massie 1973, Barnes et al 1976, Bentley 1980, Thorling 1980).

In undisplaced fractures the mean femoral head ratio was higher *** after pinning than after nailing (Table 8), while no difference was noted between the groups concerning the proportion of femoral head filling defects (Table 9).

In displaced fractures the postoperative femoral head vitality was superior in the pin group according to femoral head ratio *** (Table 8), as well as uptake deficiency ** (Table 10); vitality post fracture reduction, prior to nailing, was shown equivalent between the two groups by means of tetracycline labeling.

In the comparative investigation the total incidence of postoperative femoral head vitality reduction was 62 per cent among the Rydell nailed and 36 per cent among the Hansson pinned; this superiority of the pins was further stressed in the total material (Table 11). The difference can be explained by the methods of nail insertion. The four-flanged nail and its hook are hammered in, while predrilling of the pin channels and hook insertion with a screw mechanism for Hansson pins reduce the peroperative trauma considerably. The fracture diastasis often seen during the Rydell nail insertion might deal the ultimate blow to an already threatened femoral head vascularization.

To the 61 devices for osteosynthesis of femoral neck fractures enumerated by Tronzo in 1974 several more have been added. This calls for the need of comparing different methods but the literature records mostly retrospective investigations with varying follow-up times, often based on materials by different authors (Linton 1944, Banks 1962, Barnes et al 1976, Fielding 1980).

This need for comparative studies is further stressed by the different approaches to femoral neck fracture treatment that have evolved during the last decades. Pugh's telescoping nail (1955) was developed to allow physiological fracture compression while fracture impaction by a heavy hammer blow after fixation by 9—13 pins and plate is advocated by Deyerle (1959, 1965). Revascularization of the femoral head is the goal of muscle-pedicle grafting (Judet 1962, Meyers et al 1973, 1980) while the method of treatment presented in this study (Hansson 1975, 1982) like the von Bahr (1964) screws and the cannulated screws (Müller et al 1979, Zilch and Naseband 1980) aim at minimizing the intraoperative vascular injury. Whether screws produce the same proportion of vital femoral heads after the operation as pins remains to be investigated, and a comparative study has been initiated recently at the Department of Orthopaedic Surgery, Hospital of Helsingborg. With the von Bahr screws an incidence of early redisplacement because of screw slippage of 10 per cent has been reported (von Bahr et al 1974); this might imply an inferior mechanical stability with this osteosynthetic device. The method described here is suitable for comparing different osteosynthetic methods regarding the incidence of healing complications in controlled studies.

G. Choice of primary treatment in femoral neck fracture

Primary prosthetic replacement is a radically different approach to the treatment of fresh femoral neck fractures. This method has been used for all fractures (Hinchey and

Day 1964, Johnson and Crothers 1975, Lindholm et al 1976, Tillberg 1976) or for displaced fractures only (Raine 1973, Hunter 1980, Sim and Stauffer 1980). Indications for replacement have been considered stronger in subcapital fractures than in transcervical (Gingras et al 1980, Sim and Stauffer 1980) although autopsy studies (Klenerman and Marcuson 1970) have shown intracapsular fractures to have a fairly constant location; different rotation in the radiographs seems to be the main cause of misinterpretation. The patient's age and general condition have also been considered.

The rising frequency of mechanical loosening of prosthetic components with increasing follow-up time (Carlsson and Gentz 1980, Amstutz et al 1982) makes primary replacement unsuitable for younger patients. Half of the surviving Rydell nailed patients of the three year study healed without complications. Of those with healing complications, more than one third died, deteriorated or had insignificant symptoms. The remaining rather small part who, provided not struck by the high complication rate of primary replacement (Hunter 1980, Sim and Stauffer 1980), could have gained from this procedure, would be further reduced if internal fixation were performed with a less traumatizing method of osteosynthesis. In the one year follow-up of 134 patients (Table 12 and 13), 29 had died and six could not be followed-up, 73 (27 nailed and 46 pinned) had no signs of complications, and 26 (18 nailed and 8 pinned) had developed complications requiring reoperation in 18 cases or 13 per cent of the material. With another two years of observation, the reoperation frequency will increase but so will the mortality (Beals 1972, Jensen and Tøndevold 1979); it is obvious that primary prosthetic replacement would have been unrewarding in at least two thirds of the patients.

As primary prosthetic replacement sacrifices many a vital femoral head (Boyd and Salvatore 1964, Bauer 1979) (Figure 29), increases mortality and morbidity (Wrighton

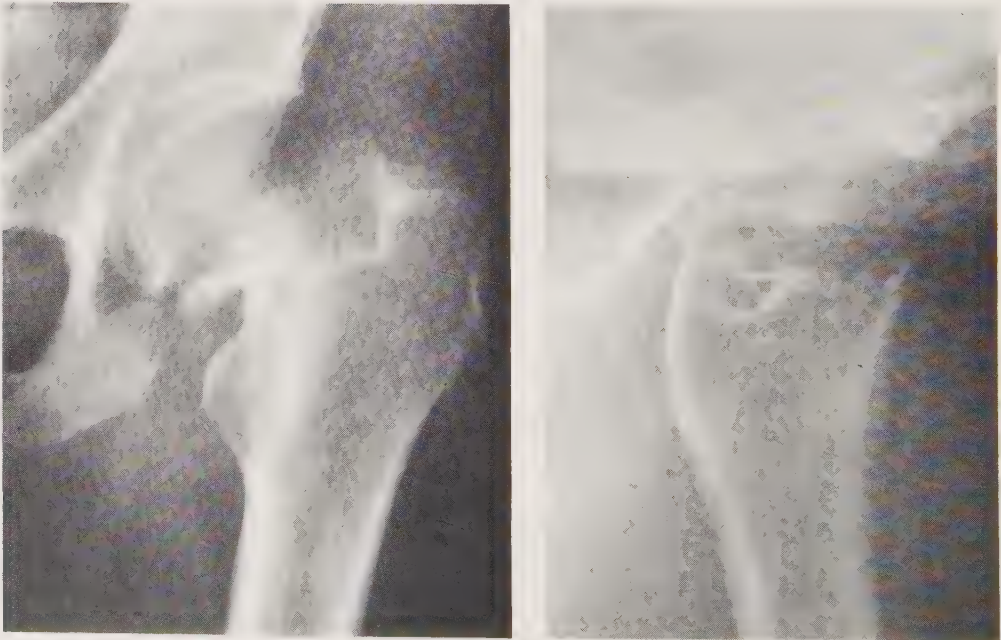


Figure 29 a Displaced fracture of the left femoral neck of 81-year old female.



Figure 29 b Scintimetry performed eight days after reduction and nailing of fracture of Figure 29 a. Femoral head ratio = 1.27 predicting normal healing.

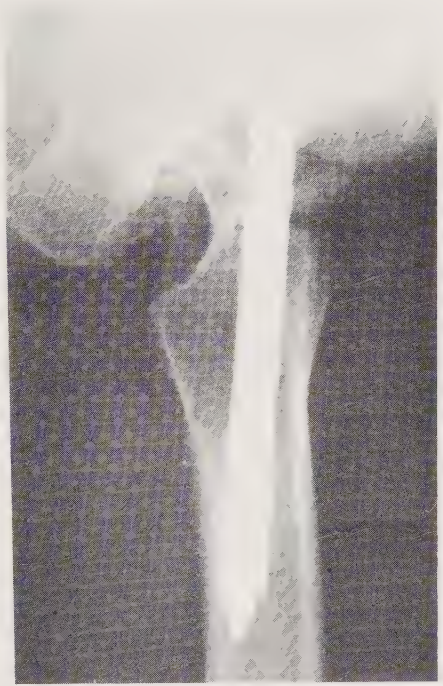
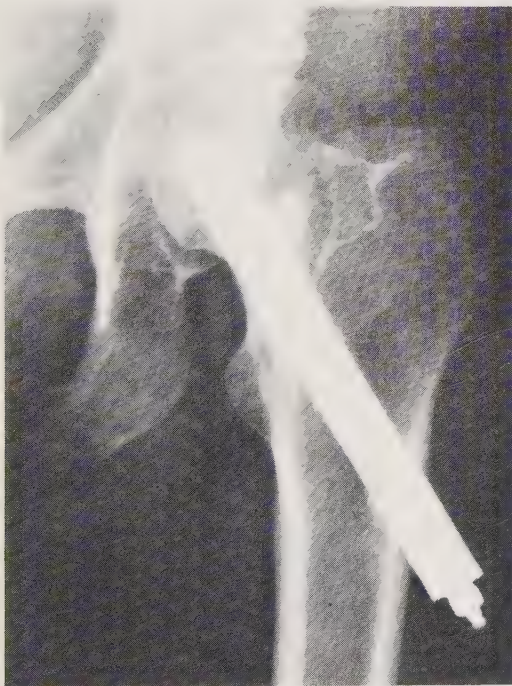


Figure 29 c Radiographic appearance three years after the operation of fracture of Figure 29 a. Fracture healing with retained shape of the femoral head is evident; the patient was asymptomatic. In many centers the femoral head of this patient would have been replaced with a prosthesis at the primary operation.

and Woodyard 1971, Hunter 1980) and doubles hospitalization expenses (Söreide et al 1980), internal fixation still should be the primary method of choice for femoral neck fracture except in selected cases, e.g. neoplastic fractures and old neglected fractures.

Non-union most often leads to severe disability while segmental collapse does so in up to 50 per cent (Boyd and Salvatore 1964, Massie 1973, Barnes et al 1976, Kofoed and Alberts 1980, Sevitt 1981); in survivors the latter figure increases with time because of progressing osteoarthritic changes (Graham and Wood 1976, Glimcher and Kenzora 1979b).

With this background the material presented here means that femoral neck fractures should be treated with internal fixation using an atraumatic technique of osteosynthesis. Scintimetry performed 1—3 weeks after the operation identifies the fractures with defective femoral head vitality. Further follow-up can be concentrated on this group only, and a secondary arthroplasty performed when symptoms develop instead of postponed until radiographic signs of complications occur.

Future investigations may reveal whether a post-fracture femoral head ischemia can be reversed by operation performed as an emergency or even by the application of pin traction. The time of anoxia tolerated by the osteoblasts also may be deduced *in vivo*. The idea of preventing revascularization of a dead femoral head (Glimcher and Kenzora 1979b) as a prophylaxis versus segmental collapse is another possible direction of evolution.

VIII General summary

The most important steps in converting the 19th century defeatistic view of the femoral neck fracture to the more optimistic approach of today have included the development of internal fixation, fluoroscopy for closed fracture reduction and the concepts of early weight-bearing and active rehabilitation. While life long disability or death awaited the femoral neck fracture patient one hundred years ago, one is now mobilized on the day after operation and rehabilitated in one's own home after two-three weeks of institutional care.

Today's problem is that of healing complications, which occur in up to 50 per cent of the fractures. Cooper's (1824) view on the central role of femoral head vitality has been confirmed by numerous investigations which have demonstrated the association of complications with femoral head vascularity and vitality. In the present investigation ^{99m}Tc -MDP scintimetry and intravital labeling with tetracycline were used to study the pre-, per- and postoperative femoral head vitality and its pro- and diagnostic significance in intracapsular fractures of the hip.

Postoperative (2—20 days) scintimetry in 39 fractures followed for three years showed the femoral head vitality decreased in 20 patients, nine of whom developed segmental collapse and ten redisplacement/non-union. Of the 19 fractures with femoral head uptake equal to or exceeding that on the non-fractured side, none developed any complications within three years. Two fractures of 19 with healing complication were undisplaced. Five out of 20 healing normally were undisplaced.

Two of those with primary uptake defects in the three-year study still had defects after four and eight months while the remaining 14 showed a transition to increased activity after four months, a pattern confirmed in subsequent investigations. For seven of eight cases reimaged already 6—8 weeks after operation, the transition had occurred already by then. The transition *per se* did not improve the healing prognosis. For the two with remaining defects after eight months, the uptake was increased after twelve months and healing complications were then evident radiographically. Not only segmental collapse but also redisplacement/non-union was thus strongly correlated to decreased femoral head vitality.

After 24 months, the difference in femoral head isotope uptake between those with healing complications and those healing normally, was highly significant. While the heads of normally healing fractures reached their peak value at 0—3 weeks (undisplaced fractures) or four months (displaced fractures) and then gradually decreased to-

wards normal, this decrease was not identified in cases destined for complications but instead a plateau or a steady increase.

The fairly constant ratio femoral head/shaft on the fracture side could be used for determination of the healing prognosis for fractures where contralateral hip disease would make comparison uncertain.

Pre- versus postoperative scintimetry in 22 fractures revealed increased femoral head uptake before the operation to be followed by increased uptake postoperatively. Preoperative uptake deficiency was followed by postoperative deficiency. One third of the fractures had an intermediate degree of femoral head uptake before operation. For these the postoperative result differed; the majority had isotope defects interpreted as effects of the operation.

In order to disclose what event during the operative procedure the vascular damage could be ascribed to, a tetracycline labeling study was performed in 370 fractures. Sixty-three patients had tetracycline administered on the day before operation and 307 patients had administration on the operation table after closed reduction, if performed, but before nailing. No difference between the two groups was found; minimally displaced fractures had relatively better labeling values. It was deduced that the vascular injury occurred after fracture reduction, and the procedure of osteosynthesis seemed likely to be responsible.

With the four-flanged nail used, several cases were observed, where a preoperative femoral head vitality consistent with uncomplicated healing was followed by decreased vitality postoperatively.

In a prospective randomized investigation through 14 months, femoral neck fractures in all patients >50 years of age were operated on with the four-flanged Rydell nail or two hook-pins. While the nail is hammered in, the cylindrical Hansson hook-pins are inserted after predrilling of the channels in order to minimize the peroperative trauma. One hundred and thirty-four fractures were included in the comparison, 61 with the nail and 73 with pins. Postoperative femoral head vitality for undisplaced fractures was reduced in 3/16 with the nail and 3/21 with pins. For displaced fractures, reduced vitality was noted in 33/45 with the nail and 23/52 with pins. This difference was statistically significant, and the mean scintimetry ratio for the hook-pin group was higher. It was concluded that a lower incidence of postoperative femoral head defects and thus a lower number of healing complications could be obtained with a less traumatic type of osteosynthesis. Comparing two different methods of osteosynthesis in a prospective randomized study has not been described in the literature hitherto.

In summary, postoperative femoral head scintimetry proved a safe complication predictor, femoral head vitality impairment by means of fracture nailing was demonstrated, and reduction of the number of healing complications was obtained with an atraumatic technique of osteosynthesis.

IX Conclusions

1. Femoral head vitality determination by simultaneous tetracycline labeling and ^{99m}Tc -MDP scintimetry correlate well.
2. Femoral head vitality within three weeks from femoral neck fracture nailing, as determined by ^{99m}Tc -MDP scintimetry, is reduced in about 50 per cent of femoral neck fractures, most of those displaced. Within less than four months a transition to hyperactivity occurs for the majority. While femoral head activity slowly decreases from four months postoperatively in normal healing, the uptake ratio increases in those developing complications.
3. Femoral head vitality determined by ^{99m}Tc -MDP scintimetry within three weeks from the operation predicts the healing course. Retained vitality is associated with uneventful healing; reduced vitality (uptake defect) spells healing complications.
4. In addition to the vascular injury caused by the fracture, further injury may occur during the operation, notably related to the nailing procedure.
5. The number of healing complications can be reduced with less traumatizing methods of osteosynthesis.
6. The current practice of primary arthroplasty for the fresh fracture of the femoral neck definitely sacrifices vital femoral heads in cases with potential for uneventful healing, and it does not benefit patients destined for early postoperative death. With attention to available techniques for primary fracture reduction and fixation and to early recognition of the need for elective secondary arthroplasty, the treatment of the intracapsular fracture of the femoral neck can be made safer for the individual and less costly to society.

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FIG. 2.

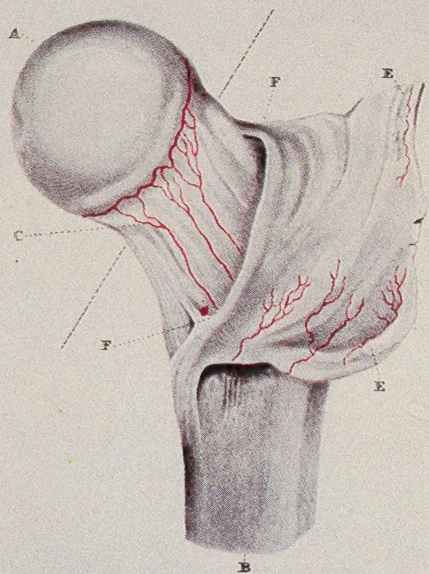
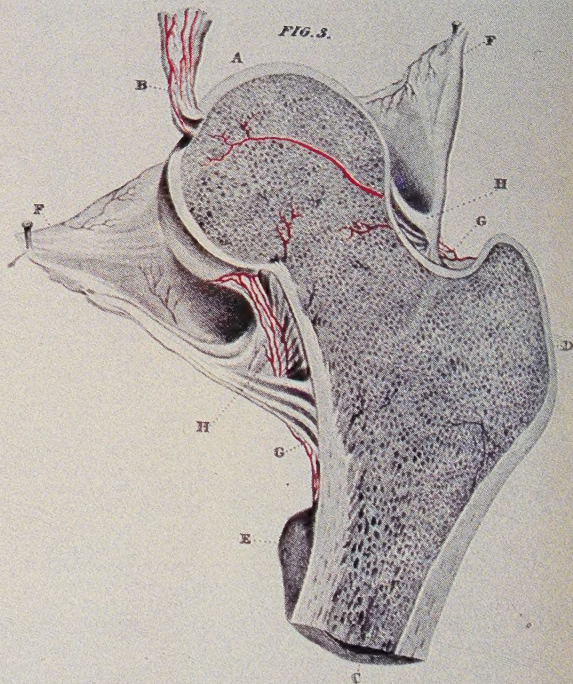


FIG. 3.



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